

Nvidia Titan X reviewed: 4K gaming on one GPU



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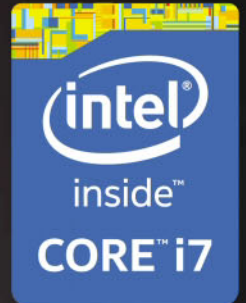
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It's a whole computer on a single PCB that costs just £30, and its quad-core ARM CPU will even run Windows 10 in the future. In this issue, we not only review the new Raspberry Pi 2, but also show you what you can do with it. There are tutorials for setting up a media streamer and file server, as well as a whole load of tips and tricks, including an overclocking guide.

Not only that, but we also cover the various operating systems available, look at some of the competing alternative boards and even show you how to make a great Pi 2 case. Whether you've yet to jump on board the hobbyist PCB bandwagon, or if you're just looking for ways to get started with your Pi 2, we've got you covered.

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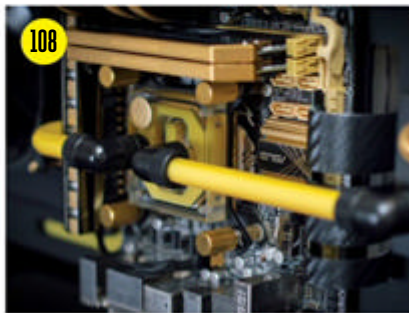


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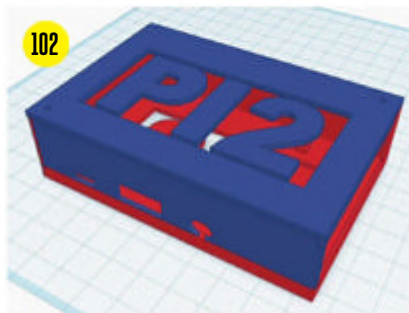
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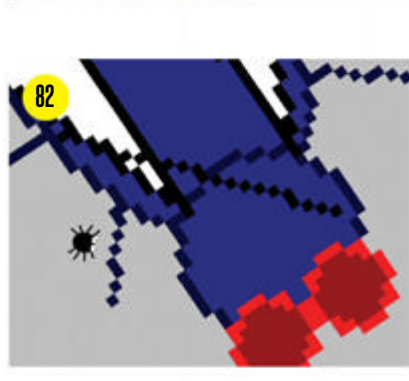
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BEN HARDWIDGE / FROM THE EDITOR

TITAN X WORLD

Ben Hardwidge struggles to rationalise the cost of a Titan X, while still wanting one

I imagine trying to rationalise the cost of an Nvidia Titan X (see p18) to someone in the real world. You know, the one where people can watch a Hollywood movie without cringing at all the technological inaccuracies, and they aren't expected to fix their families' computers. You've basically just spent £869 on a PCB with a fan on it, and you show it your mate who isn't into PCs, tell them the price and they give you that blank-eyed look that contains equal measures of horror and bafflement, before saying something like 'wow, I bet that's got a lot of RAMs'.

I've tried to think of an equivalent example among other high-margin premium products, but I keep coming up with nothing. Take premium Swiss automatic watches, which are undoubtedly really well made, and have gorgeous mechanical movements, but are still basically just overpriced watches, marketed by models and actors in dubious lighting conditions. I say this as someone who proudly owns a Swiss automatic. It's lovely, but it's also undoubtedly a poor performer in the bang per buck charts.

However, with a Swiss watch you're making an investment – look after it, and it could well last for your entire life. The same couldn't be said for a graphics card. Then I thought about sports cars, Gibson guitars, fancy hi-fi equipment, 4K TVs, carbon fibre mountain bikes and so on. In every case, the extra money buys you a long-term investment – it's expensive, and you get diminishing returns as the price goes up, but at least you get a good amount of use out of your purchase.

The nearest equivalent to the Titan X I could imagine was a 128GB iPhone 6 Plus, which will probably stop getting new operating system updates within four years, and generally comes supplied with a two-year contract. But even an

It sits in a PC, playing games, costing the same as three Xbox Ones, and deteriorating in value quicker than a CRT TV

expensive smartphone is a better investment than a really expensive graphics card. A smartphone does almost everything you could ask from a general computer in a device the size of your pocket, from playing music and video, to using social media and accessing the Internet, plus thousands of other jobs you can assign to the many available apps.

It isn't as though the Titan X even supports double-precision compute for workstations – it's purely for games. That's all it does. It sits in a PC, playing games, costing the same amount as three Xbox Ones, and deteriorating in value quicker than a CRT TV.

Yet despite all of the above, I still watched the Nvidia Titan X presentation in the same way Homer Simpson looks at doughnuts. It wasn't just a little better than a GTX 980 – it was a significant step up, with over 3,000 stream processors. 'I bet that could play games at 4K,' I thought, and it turns out it can do exactly that, although it's pretty near the knuckle.

That's still a brilliant engineering achievement for Nvidia though – 4K gaming on one GPU, without over-the-top cooling or sky-high power requirements. It makes 4K gaming a genuine possibility in a small mini-ITX rig, and it means you don't have to own a dual-GPU system to play games at 4K too, although undoubtedly several willy wavers will build systems containing three or four Titan X cards, completely defeating the point of them.

The Titan X is an incredible feat of technical engineering. I want one. I really want one. And that's the problem. I know it isn't worth the money. I know it will be practically worthless in five years – it can only just play a two-year-old game at 4K now. I know it's only good for games. Yet I'd snap one up if I had the cash. It's a good job I don't. **GPC**

Ben Hardwidge is the editor of Custom PC. He likes PCs, heavy metal, real ale and Warhammer 40,000. editor@custompcmag.org.uk [@mandogfish](https://twitter.com/mandogfish)



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TRACY KING / SCEPTICAL ANALYSIS

GAMES TESTING TRAINING COURSES

Is it worth paying five grand for a course on games testing? asks Tracy King

Recently I received an excited text from a young relative who was planning on paying for a course that would, in his words, 'help get a job making video games'. The course turned out to be for 'testing', Quality Assurance (QA) training, and he wanted to know if it was worth the £5,000 fee.

The answer, of course, is 'it depends'. All education is worth something, and we're currently paying £9,000 a year fees for degrees, making private and shorter courses or certificates seem like a bargain. However, some course providers seem to have realised that an entire generation of gamers wants a dream career in games, and are happy to provide training that has little resemblance to industry jobs.

Testing is one of these areas. Yes, there's often more to games testing than sitting around playing games, but often there isn't. Sometimes you sit in a hot, sweaty, stinky teenager-filled room for 16 hours a day. You play the same buggy, broken level over and over for hours, and fill in a form. The work is rarely more than temporary, but you wouldn't want it to be permanent anyway.

But yes, that work is a foot in the door of a game company, a name on your CV, and that can be invaluable. But do you have a better chance of securing an entry-level role with a paid-for certificate from a private educator under your belt?

Probably not. A qualification of any kind is hard proof that you can stick at a project, but most studios are looking for enthusiasm and experience in gaming more than certification. If you want to test video games, you can buy a game on Steam with early access and play the beta, watch the developer's Twitch streams and take notes—that will look as good on your

CV as a City and Guilds in QA testing. Heck, you can even email indie developers and offer to beta-test for them in return for a copy of the game. Offer to sign a non-disclosure agreement and they may well agree.

On the promise of anonymity, I asked three studios—a triple A, a medium-sized independent company and a one-man indie—the same question: what are your priorities when assessing a candidate? All three gave a variation of the same answer. Experience, enthusiasm and communication skills take precedence over formal qualifications.

It's easy to see why. People who make video games (my own small company included) often start as bedroom coders and hobbyists. Some go on to study computer science or related subjects at university, others choose graphic arts, and some choose a subject they can fall back on should their dream of making games not come to fruition. Some skip higher education entirely and just make stuff.

The industry has long suffered from a 'crunch' culture of excessively long hours and mandatory weekends to meet deadlines. Crunch has become the standard, and can be prohibitive to women (who still bear the majority of the childcare burden), older people and those with disabilities. But those people have dreams of making video games too.

And that's how the private education companies thrive. The dreams of people who want to make games instead of being a plumber. Even Mario wasn't satisfied with his career, preferring instead to rescue Peach while getting paid in random gold coins. He just wasn't charged five grand for the castle-invasion training. **GPG**

Most studios are looking for enthusiasm and experience in gaming more than certification

Gamer and science enthusiast Tracy King dissects the evidence and statistics behind popular media stories surrounding tech and gaming [@tkingdoll](#)



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Letters

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Settle a bet

Respectfully, is it possible that in the third paragraph of Tracy King's column, Stock and Bull, that she meant roulette tables, and not blackjack tables? My confusion is that I see roulette tables displaying running tallies of numbers, but never blackjack tables. Of course, the gaming industry in the UK may operate differently than here in Ontario, Canada.

MORRIS BUCKNER

(A retired provincial gaming inspector)

Tracy: Hi Morris! Yes indeed, I did mean roulette tables, thanks for spotting my mistake. I blame a lack of coffee.



That's no micrometer!

Thanks for a great magazine, which I've been following since Issue 13. However, I'd just like to point out an inaccuracy that I'm sure has occurred before in one of your technical articles: the caption for the picture at the top of p90 in Issue 141 describes a 'micrometer' being used to take measurements, when in fact the tool being used is a digital vernier caliper. A micrometer looks (a little) like a small G-clamp and, although it can measure more accurately than a vernier, it wouldn't fit into the gaps around the ports as shown in the photo.

The vernier being used is a much more appropriate tool for hobbyists, as they're readily available in the digital version shown for under £20, and can measure external dimensions (as illustrated), internal dimensions (using the other jaws) and also depths. You would need three different micrometers (internal, external and depth). Additionally, a digital vernier



This is a digital vernier caliper, not a micrometer

usually has a range from 0-150mm, whereas a micrometer typically only measures in 25mm increments, such as 0-25mm.

TIM MOGGERIDGE

Antony: Tim, you're absolutely right – thanks for clearing that up – we'll change the wording from this issue onwards. I'm glad we're actually using the best tool for the job, though, and I'm pleased you like the guides!

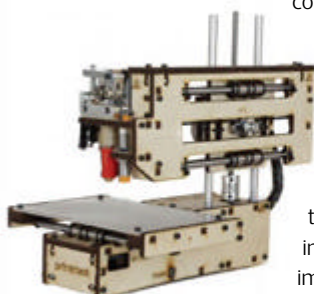


3D printer price

Where did you get your price of 'less than £250' for the Simple Maker's Kit? The best I can find is £360 inc VAT (also it's Printbot, not Printbot). I hope you can help, as £250 is my maximum at the moment.

CENYDD

The Simple Maker's Kit costs £236, but you need to ship it from the USA



Ben: That price was taken direct from the Printbot (yes, not Printbot!) website (<http://printbot.com>), converting the dollars into pounds – I don't think we could find a direct supplier in the UK at the time. At the current exchange rate, the price in dollars is \$349 (£236), with £74 (£50) required for carriage to the UK – the total is £286, excluding any import duties that may be imposed. Sorry that wasn't

clear in the feature (I think it was only mentioned in a caption) – it doesn't look like you'll be able to get it for less than £250 in the UK, which is a shame – £360 is a pretty massive markup.



Should I buy a GeForce GTX 960?

After several years of enjoying and subscribing to **Custom PC** magazine, I need to make a suggestion and ask your opinion. I've recently been waiting for such a graphics cards review as you did this month (Issue 140), as I'm now looking to add a discrete card instead of relying on the motherboard graphics via HDMI.

Despite my preference being Nvidia graphics for ages, being led by your expert opinions, I'm torn between the Radeon R9 280 or 280X and the GeForce GTX 960. I'm not bothered about overclocking, but I'm interested in (on top of fps) the card's noise levels, and whether it's future-proof.

My budget is a maximum of £200, and normally I'd just go for your approved card, but I'm bothered by the Radeons' 'older hardware' (missing out on TrueAudio and FreeSync), thus affecting future-proofing, as well as their lower efficiency and noise levels compared with the GeForce GTX 960.

Can you please consider including other real-world attributes in your scoring, such as efficiency, quietness and future-proofing? Based on what I've said, would you still put the Radeons above the GeForce 960? If so, why?

DAVID BLAKE

Ben: There are a lot of issues at play here, so I'm going to break it down into

Can you please consider including other real-world attributes in your scoring, such as efficiency, quietness and future-proofing?

a few parts. Firstly, last month's Labs test was really a GPU group test, as opposed to a graphics card test – we wanted to see which specific GPU configurations would offer the best bang per buck in terms of playable frame rates, and on those terms, the Radeons win.

Secondly, I don't know if you noticed, but we did actually include efficiency in the scoring of each GPU too, but the Radeons still won out after AMD's aggressive price cuts. In terms of future-proofing, I wouldn't be too worried about TrueAudio support, and FreeSync is only going to be an issue if you specifically buy a FreeSync monitor. I wouldn't worry about future proofing with these cards, to be honest.

Thirdly, and perhaps most importantly for your purposes, most GPUs are sold in a number of different SKUs by board manufacturers, with third-party coolers, many of which are quieter and more efficient than others. When we review a specific graphics card (rather than just a GPU), we do account for noise and efficiency in the verdict and score, but we can't do that for a GPU, as there are so many variables that are down to specific cards, rather than the GPU itself.

What you need to ask yourself is which resolution you'll be using to play games, and whether noise and efficiency are bigger priorities to you than bang per buck (which sounds like it's the case). If so, a GeForce GTX 960 card may well be a better bet for you if you're only playing games at 1080p – it handles every game fine at this resolution and, as we say in the review,



the 960's low heat output and efficiency make it much more appropriate for cards with quiet, semi-passive cooling systems. What you sacrifice, however, is the ability to play more games at 2,560 x 1,440, and you'll pay more for it too.

As such, we mainly base our scoring on the number of minimum frame rate targets hit, compared to the price, with efficiency only taking up 10 per cent of the score, as that's what most PC gamers are interested in. However, if you have different priorities, you still have all the information in that group test to make a buying decision – it sounds like the GTX 960 may well be more appropriate for your purposes.



Under the board

After reading Mark Gardener's letter in Issue 139, and the reply by Ben, I felt I needed to write. I agree with Mark that it would be much easier and neater for power connectors to be on the board. However, Ben replied that you'd need to dismantle your PC to refit a loose connector under the board. That would not be so. I've built many PCs, and only one didn't allow access to the underside of the motherboard. It normally just involves two thumbscrews on the side of the case. I normally put

WHEN'S THE NEXT MAG COMING OUT?

Issue 142 of Custom PC will be on sale on Thursday, 21 May, with subscribers receiving it a few days beforehand. Visit <http://tinyurl.com/CPCDates> to see the release dates for the rest of the year.



Twitter highlights

Follow us on Twitter at @CustomPCmag



kajun_cheng Thanks for filling up my evening tonight!



TheNo1Hozza Great issue – loved the 3D printer article so much so I've parted with some cash on MAKIBOXCLEARANCE. Now look what you've done.



georgebaily Lol 'feature sprint...Feature creep gone into overdrive' Gorbald of @CustomPCMag on crowdfunded victims of own success.



DbaHenderson I could frame the subscribers covers for @CustomPCMag

unsightly cables behind the motherboard anyway.

Motherboard manufacturers could also put the accessories in the box and allow the builder to choose if they want a simple build, or a neat, tidy (and cooler-running) PC. I'm all for Mark's idea of more choice of connectors built onto the board.

NORMAN STEPHENSON

Ben: I think you might have misunderstood my point, Norman – I also use the area behind the motherboard tray for hiding cables, like any other good PC builder. The point is that many cases don't allow immediate access to the underside of the motherboard itself, rather than the tray.

Some cases have large cut-outs, but they vary in size and positioning – it would be hard for a motherboard manufacturer to anticipate exactly where you would be able to access the underside of the motherboard. If you had smaller connectors at the edge of the underside, then you could access them between the standoffs, but you're not going to have much room, especially for big power connectors.

Don't get me wrong, I love the idea, I just think it would be hard to implement properly. **GPG**

Send your feedback and correspondence to letters@custompcmag.org.uk

Incoming

We take a look at the latest newly announced products

ASRock gives X99 mini-ITX treatment

ASRock has finally answered the demands for tiny but more powerful PCs, by squeezing an LGA2011-v3 platform onto a mini-ITX motherboard with an X99 chipset. Sadly, there's no room for the full count of four DIMM slots needed for quad-channel memory, so there are only two memory slots instead.



Otherwise, though, the X99E-ITX/ac provides all the makings of a mini multi-threaded monster, including a 16x PCI-E 3 slot, six right-angled SATA 6Gbps ports, an M.2 connector, 802.11ac Wi-Fi and support for USB 3.1. The board also comes bundled with a low-profile CPU cooler with a side-mounted fan.



EVGA launches hybrid GTX 980

After making loads of Nvidia cards fitted with either air coolers or waterblocks, EVGA has just announced a mix of both cooling systems for its latest GeForce GTX 980 Hybrid card. The card comes with a closed loop liquid-cooling system, featuring a 120mm radiator, while the pump and waterblock combo has a copper base.



According to EVGA, the system allows for 'virtually silent operation', thanks to variable fan speed control, while the cooling system for the

VRMs and memory chips is kept separate from the GPU cooling setup. In addition to the Hybrid card, EVGA says it will also offer the liquid-cooling system separately as an upgrade kit. There's no word on UK pricing and availability yet, but EVGA says that the pricing on the continent will be £779 (£567) for the card, and €119.90 (£87) for the upgrade kit.

Enermax launches fanless PSU

Enermax has launched a new 550W fanless power supply, which also comes with digital monitoring and control software. As well as guaranteeing silent operation, the Digifanless PSU is fully certified with 80 Plus Platinum efficiency, has individually sleeved modular cables and a warning not to block its air vents. Meanwhile, the ZDPMS software enables



you to monitor the PSU's temperature, efficiency and power output, while also giving you control over certain features, such as switching from single-rail to multi-rail 12V operation. Using a single 12V rail, the Digifanless can handle 45A of 12V current. The Digifanless is available to pre-order from www.scan.co.uk now for £180 inc VAT.

STOP PRESS

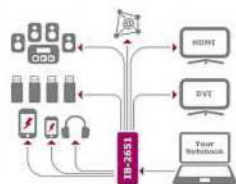
Intel SSD 750 1.2TB

Our good pals at Asus in Taiwan have managed to get their hands on a preview sample of Intel's new SSD 750, as part of a bundle deal that will be available with some of the company's TUF motherboards in the future, and they very kindly ran some benchmarks on it for us. The drive uses the NVMe (non-volatile memory express) host-side protocol, rather than AHCI (which we discuss in more depth on p46), and its use of the PCI-E bus means it can dish out some hefty performance by the looks of it.

In AS SSD, the drive managed some very fast sequential read and write times of 1,586.8MB/sec and 1,254.8MB/sec respectively. Interestingly, though, the 4KB random read speed dropped right down to 27.5MB/sec, with a healthier random write speed of 140.9MB/sec. We'd like to thank Asus for giving us this preview, and we look forward to giving the 750 a full workout in our benchmark suite at a later date.

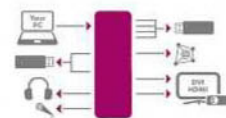


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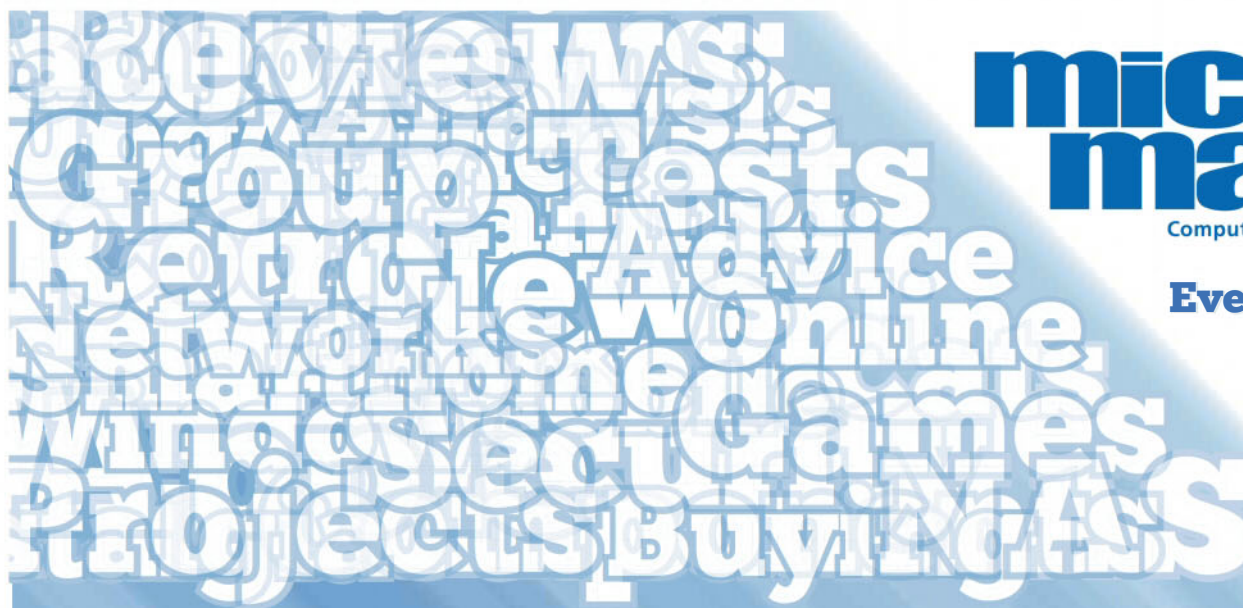


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Computing in the know

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Reviews

Our in-depth analysis of the latest PC hardware



Reviewed this month

Corsair Hydro Series H80i GT p17 / Nvidia GeForce GTX Titan X p18 /

Ambros Gigabyte BRIX S GB-BXi5H-5200 p20 / Phanteks Enthoo Mini XL p24 /

MSI GT80 2QE Titan SLI-023UK p26 / SteelSeries Apex M800 p30 / HyperX Cloud II p32 /

CPU COOLER

Corsair Hydro Series H80i GT / £81 inc VAT

SUPPLIER www.scan.co.uk / MODEL NUMBER CW-9060017-WW

The H80i GT picks up from where its predecessor left off, with the 'i' after the model number signifying its compatibility with Corsair's Link control software. There's a mini USB port on the side of the pump section, and an included cable connects it to a motherboard USB 2 header. As we saw with the H110i GT last month, the latest version of the Link software offers masses of customisation and control, and you can even adjust the RGB lighting on the pump section to your own preference, or just to indicate the coolant temperature.

You can also use it to control the speed of the H80i GT's fans, running at a fixed speed or assigned to one of several preset modes, such as Quiet or Performance. You can change the temperature input to the coolant or the CPU temperature too. Being able to change the pump speed is useful as well as, until now, it's only been possible on custom water-cooling pumps, although the H110i GT was only a little quieter at its lowest setting.

The cooler itself uses a single 120mm-fan radiator that's 49mm thick, along with the same large, braid-covered tubing that's present on the H110i GT. However, with the smaller H80i GT, the tubing's lack of flexibility can get in the way when squeezing it into tight spaces. It's practically impossible to kink, but it doesn't bend as easily as previous models' tubing. The H80i GT also

ships with two fans, allowing push-pull setups – these fans add 25mm a piece to the depth, so you'll need at least 100mm of clearance in front of a spare 120mm fan mount.

Meanwhile, the fairly large pump section is powered by a 3-pin fan header, while a splitter cable attached to the pump section allows you to power both fans from the cooler, although you'll still need to contend with a number of cables. Thermal paste is pre-applied.

The H80i GT's performance was more susceptible to low fan and pump speeds than the H110i GT, with big differences between minimum and maximum settings. It was cooler than the H75 at maximum speed, but the H110i GT performed better still, particularly at lower fan speeds. The

H80i GT is blissfully quiet at low speed, though, and the pump is one of the quietest all-in-one liquid-cooler pumps we've heard at this setting.

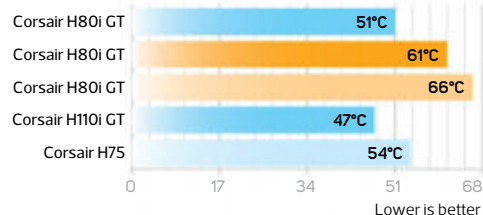
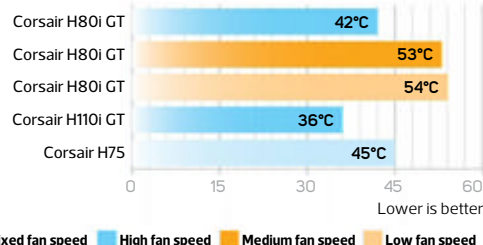
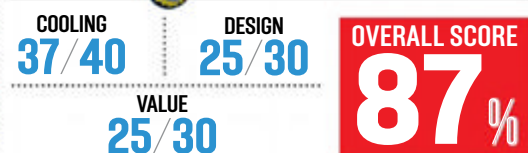
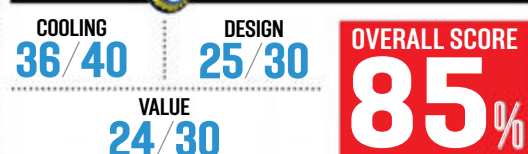
Conclusion

If you can't fit the humongous the H110i GT in your case, but still want to Corsair's excellent Link software, the H80i GT is a great choice. It provides better cooling than the H75 and is very quiet on minimum settings, albeit at the cost of cooling power.

ANTONY LEATHER



You can even adjust the RGB lighting on the pump section

**INTEL LGA1150 DELTA T****INTEL LGA2011 DELTA T****LGA115x****LGA2011****VERDICT**

Excellent cooling at full speed, and Corsair's Link software is great. It's very quiet at low settings too, although cooling ability suffers as a result.

/SPECIFICATIONS

Compatibility Intel: LGA2011, LGA2011-v3, LGA115x, LGA1366, LGA775; AMD: Socket AM3+, AM3, AM2+, AM2, FM2+, FM2, FM1

Radiator size with fans (mm) 154 x 123 x 99 (W x D x H)

Fans 2 x 120mm

Stated noise Up to 37.7dB(A)

GRAPHICS CARD

Nvidia GeForce GTX Titan X / £869 inc VAT

SUPPLIER www.scan.co.uk

On paper, the Titan X's new GM200 GPU is 50 per cent faster than the GTX 980's GM204. It is a 28nm part with a 601mm² die size and a massive 8 billion transistors. GM200 is still divided into graphics processing clusters (GPCs) with four Streaming Multiprocessors (SMs) apiece, and each of these SMs again has 128 stream processors. However, while GTX 980 had four GPCs, the Titan X adds another two, both of which are fully enabled. This takes the number of stream processors to 3,072 and the texture units to 192. Clock speeds are a little lower, but with the base clock at 1GHz and the rated boost clock at 1,075MHz, there's a lot of potential.

There are six memory controllers too – a 50 per cent increase over the GTX 980, making for a fat 384-bit interface. With Maxwell, memory controllers are tied to ROP and L2 cache partitions, so the number of ROPs has increased from 64 to 96, and the L2 cache from 2MB to 3MB. Nvidia has also equipped the Titan X with 12GB of VRAM, enough to deal with 4K gaming and high-resolution textures. Once again, the memory is clocked at 7GHz, giving the Titan X a total memory bandwidth of 336GB/sec.

The Titan X supports DirectX 12, as well as Nvidia's latest visual and virtual reality technologies. However, it doesn't have unlocked double-precision compute performance like previous Titan cards; instead, it's locked at the driver level, as with the GTX 980. Titan cards have always been adrift from the typical price-performance curve, partly because they unlocked double-precision performance for workstation users. Now, however, the price is the same but the Titan is purely for gaming, with Nvidia directing customers to its Quadro products for compute purposes. The Titan X also lacks Nvidia's latest display engine, so it doesn't offer hardware-based H.265 decoding like the GTX 960, which is more suitable for HTPC use.

The card will only be sold with the reference heatsink, although third-party waterblocks are available. Once again, there's an anodised aluminium covering, this time mostly black, with a green, backlit GeForce logo on top. There's no backplate, so no direct cooling for the rear memory chips, but the other components are well covered. The GPU is cooled by a copper vapour chamber while the remaining memory chips and the MOSFETs of the 6+2 power phases are cooled by a metal contact plate. This is all connected to a large aluminium heatsink, with a single fan that exhausts most of its heat through the rear I/O panel.

Elsewhere, it's business as usual. The 6-pin/8-pin PCI-E power combination is the same as the original Titan; both cards have a 250W TDP. Meanwhile, 4-way SLI is possible with the dual SLI connectors, and the

modernised set of video outputs includes support for up to 5K resolutions and up to four 4K panels. Finally, Nvidia says the GTX Titan X is a better overclocker than the original Titan, thanks to a higher maximum power target and improved VRM circuitry and components.

Performance

The GTX Titan X clearly asserts itself as the new fastest single GPU card. Going by minimum frame rates, it leads the GTX 980 by 37 per cent across our games, and the R9 290X, AMD's current champion, by a massive 47 per cent. Even pairing two of AMD's fastest GPUs together in the R9 295X2 doesn't leave the red team that far ahead in many cases.

At 2,560 x 1,440, the Titan X dominates, cruising at over 60fps in all games except Crysis 3, where it isn't far off at 57fps. As such, it offers a noticeably smoother experience at this resolution than any other single-GPU card. The R9 295X2 is generally quicker, (just) managing a minimum of over 60fps in Crysis 3, but conversely, its minimum frame rate is only 56fps in Shadow of Mordor compared to 68fps for the Titan X, despite its 3fps higher average, showing the inconsistencies multi-GPU users still face.

At 4K, the Titan X is finally the first single-GPU card to meet the technically playable frame rate target of 25fps minimum in every test. In fact, in every game but Crysis 3, its minimum is comfortably above 30fps too.

The power figures are fantastic too; the massive gap of almost 300W between the R9 295X2 and Titan X

/SPECIFICATIONS

Graphics processor Nvidia GeForce GTX Titan X, 1,000MHz (boost 1,075MHz)

Pipeline 3,072 stream processors, 96 ROPs

Memory 12GB GDDR5, 7GHz effective

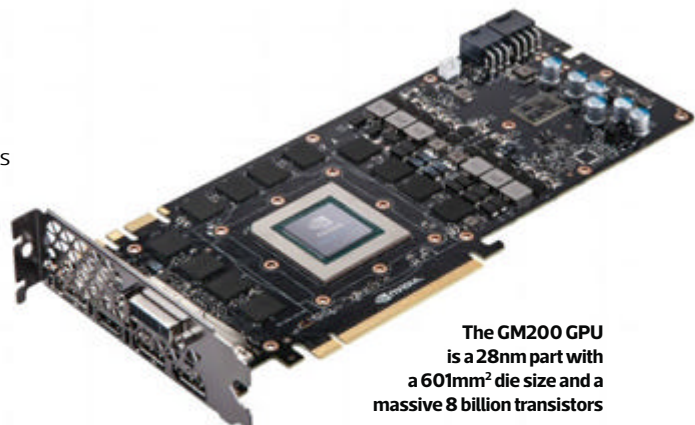
Bandwidth 336GB/sec

Compatibility DirectX 12, OpenGL 4.5

Outputs/inputs 3 x DisplayPort, Dual-link DVI-I, HDMI

Power connections 1x 8-pin, 1x 6-pin, top-mounted

Size 267mm long, dual-slot



The GM200 GPU is a 28nm part with a 601mm² die size and a massive 8 billion transistors

demonstrates Maxwell's efficiency yet again. It consumes a little more than the Sapphire R9 290X we tested, but we've seen reference R9 290X cards consume even more power than the Titan X. With regards to noise, the reference cooler under load is clearly audible but not loud or intrusive.

Through overclocking, we managed to overclock the base clock to 1,192MHz, where it boosted to between 1,341MHz and 1,366MHz under sustained load. The memory was also stable all the way up to 2GHz (8GHz effective). These settings gave us a performance boost of between 14 and 18 per cent in most cases, although the minimum in Crysis 3 jumped to a much smoother 33fps at 4K. The fan speed also increased slightly – again, not quite to intrusive levels, but enough that we'd rather water-cool the card to get the most benefit from overclocking.

Conclusion

The GTX Titan X reasserts Nvidia's current dominance when it comes to performance and efficiency. It's certainly cheeky

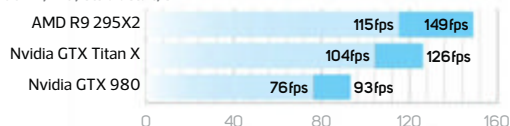


to charge the same price as the original Titan without offering unlocked compute performance, and you can gain more performance with a significantly cheaper CrossFire or SLI setup. However, for single GPU-performance, which is the only realistic option in some smaller systems, the Titan X is entirely without competition.

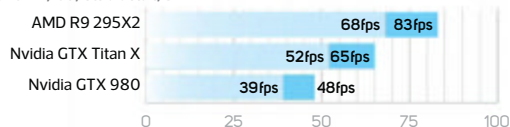
MATTHEW LAMBERT

ALIEN: ISOLATION

2,560 x 1,440, Ultra detail, SMAA T2x

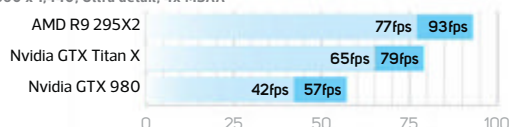


3,840 x 2,160, Ultra detail, SMAA T2x

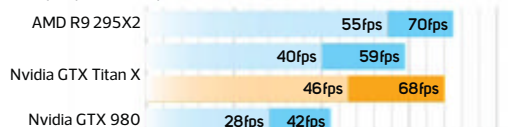


BATTLEFIELD 4

2,560 x 1,440, Ultra detail, 4x MSAA



3,840 x 2,160, Ultra detail, 0x MSAA

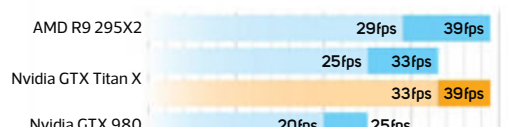


CRYSIS 3

2,560 x 1,440, Very High detail, 0x AA



3,840 x 2,160, Very High detail, 0x AA

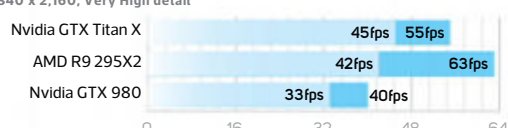


MIDDLE EARTH: SHADOW OF MORDOR

2,560 x 1,440, Ultra detail

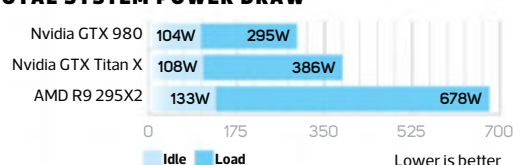


3,840 x 2,160, Very High detail



Stock speed min Stock speed avg Overclocked min Overclocked avg

TOTAL SYSTEM POWER DRAW



SPEED
40/40
FEATURES
18/20
VALUE
17/40

OVERALL SCORE
75%

VERDICT

An impressive display of power from the green team; the Titan X is unmatched for performance and efficiency, although the price is ridiculous.

MINI PC

Ambros Gigabyte BRIX S GB-BXi5H-5200/

£630 inc VAT (as reviewed), **£324** inc VAT (bare bones)SUPPLIER www.ambros.co.uk

Quite a few companies have jumped onto the mini PC bandwagon in the wake of Intel's NUC form factor. Most motherboard manufacturers, for instance, have a presence and we saw Asus' Core i5-4210U-based VivoMini. Gigabyte is certainly no stranger to tiny PCs either, and its BRIX range of bare bones units has even included a GTX 760 GPU before now. This month, we're looking at its latest Intel Broadwell-based BRIX S GB-BXi5H-5200.

As its name suggests, this model uses an Intel Core i5-5200U, which launched earlier this year and is identical to the mobile CPU found in the latest laptops and ultrabooks. It has a base frequency of 2.2GHz but it also supports Turbo Boost, so it can ramp up to 2.7GHz when under load. Similarly, it can drop down to just 600MHz under light loads, dropping the TDP from a maximum of 15W to just 7.5W.

The BXi5H itself comes in barebones form with no storage or memory, although mini PC specialist www.ambros.co.uk provided our customised sample, which comes with 8GB of RAM, a 1TB Samsung hard disk and a 120GB Kingston mSATA SSD. The bare bones option costs £324 inc VAT, while our sample, which includes Windows 8.1

pre-installed along with an M.2 (Type 2230/30mm) Intel Wireless-AC 3160 card, will set you back £630, but you can customise the system to use less RAM or just include an SSD for example. The full system price also includes a one-year parts and labour warranty from Ambros.

Apart from the plastic lid, the case is made from steel and aluminium. Like Intel's NUC systems, there's a U-shaped fan for cooling, which exhausts air through the rear of the case. There are plenty of ports too, with a full-sized HDMI port along with a mini-DisplayPort, and four USB 3 ports split between the front and rear of the case. There's also a combined headphone/microphone mini-jack and Gigabit

Ethernet port. The only noteworthy omission when compared to the VivoMini is an SD card reader.

The BXi5H sports a VESA monitor mount, allowing you to fix the case to the rear of compatible monitors to save space, although the base is equipped with small rubber feet so it's equally at home on a desk. The actual PCB is devoid of SATA connectors, but there's a proprietary connector that both powers and provides a data connection for 2.5in SATA hard disks or SSDs, with a 2.5in mount in the base, where the 1TB Samsung hard disk in our sample is located.



As per usual with this type of motherboard, there are two SODIMM slots that support up to 8GB of RAM per slot and these slots, as well as the mSATA slot, are all easily accessible by popping off the base section if you're planning to install your own hardware.

Performance

As the first Broadwell-based CPU to come through our lab, the Core i5-5200U's reputation preceded it. Thankfully, we weren't disappointed. It was considerably faster than both Haswell Core i5 chips we've previously reviewed in similar mini systems, including the Core i5-4210U in the Asus VivoMini. The image editing test saw it add another 4,500 points to the score of the VivoMini and over 7,000 to the score of the Core i5-4250U – equivalent to 14 per cent and 26 per cent faster respectively. It was a similar story to the other tests, with the BXi5H's system score being over 7 per cent quicker than that of the VivoMini.

Of course, the main focus of Broadwell is improving power efficiency, and the BXi5H impressed here too. Despite having a 2.5in hard disk in tow compared to the other systems, it consumed just 1W more power at idle and its load power draw was 4W lower than the Core i5-4210U-powered VivoMini too.

Sadly, when we disconnected the hard disk, the BXi5H failed to boot, so we couldn't get into Windows to obtain results without the hard disk installed, but under load, it consumes nearly 13 per cent less power than the VivoMini. The Core i5-5200U doesn't add much more gaming performance to the equation, though, as our Skyrim test

Like NUC systems, there's a U-shaped fan for cooling

/SPECIFICATIONS**CPU** Intel Core i5-5200U**Memory support** 2 x SODIMM slots: max 16GB DDR3 (up to 1,600MHz, 1.35V)**Networking** Gigabit LAN, 802.11ac Wi-Fi**Ports** 4 x USB 3, mini-DisplayPort, HDMI**Storage** 2.5in drive bay, mSATA slot, M.2 Type 2230/30mm slot**Dimensions (mm)** 114 x 108 x 47

- 1** Ambros supplies a 120GB Kingston mSATA SSD with the BXi5H
- 2** Our system came supplied with 8GB of dual-channel memory
- 3** A proprietary connector provides data and power for a 2.5in SATA drive

only saw 1fps added to the minimum frame rate, although the result is what we consider to be borderline playable.

Noise-wise, the BXi5H is very quiet during low to medium loads, where the hard disk was louder than the cooling fan. However, when you throw some heavy loads at it, such as Prime95's smallfft test, the fan spins up quite a bit, making it noticeably louder than the VivoMini under the same conditions. However, the BXi5H's temperature was also much lower; the VivoMini topped out at a delta T of 56°C, with a temperature of 80°C reported in CoreTemp. The BXi5H never went above a delta T of 47°C, with CoreTemp maxing out at 71°C. Clearly, there's room for less aggressive fan speeds, but sadly you can't alter them in the BXi5H's EFL.

Conclusion

The BXi5H is fast for a NUC-like PC, and it's also very power-efficient. The fact you can add a 2.5in drive as well as an mSATA SSD means you have everything you need to create a capable HTPC or home server, and its peak power draw of less than 30W adds to the appeal. It's a shame it's noisier than Asus' VivoMini, though, especially when the CPU was actually running much cooler than the Asus VivoMini's chip.

Price-wise, it's also £50 more expensive than the VivoMini in bare bones form, but it justifies that price with its

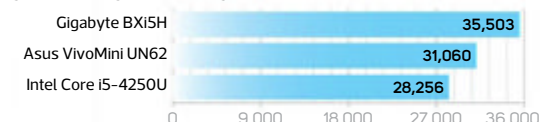


superior speed and power consumption. Ambros has also done a great job of putting together a BRIX system – if you need a quiet, low-power PC, then this machine is worth the extra cash over a similar Haswell-based NUC.

ANTONY LEATHER

CUSTOM PC REALBENCH 2014

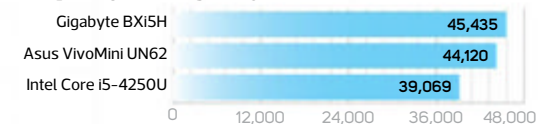
GIMP IMAGE EDITING



HANDBRAKE H.264 VIDEO ENCODING



HEAVY MULTI-TASKING



SYSTEM SCORE



THE ELDER SCROLLS V: SKYRIM

1,280 x 720, 0x AA, 0x AF, High settings



TOTAL SYSTEM POWER CONSUMPTION



SPEED
21/25

FEATURES
23/25

DESIGN
21/25

VALUE
18/25

OVERALL SCORE
83%

VERDICT

Broadwell is fast and power-efficient, making Gigabyte's mini PC worth the premium over Haswell-based NUCs if you need the extra speed.

Performance without compromise



Infinity 7850K

- AMD A10-7850K APU
- ASUS® A88XM-PLUS
- 8GB HyperX FURY RAM
- Integrated AMD Radeon™ HD 8000
- 2TB Hard Drive
- **Windows 8.1**
- 3 Year Standard Warranty

THIS SPEC FROM **£499***



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- ASUS® H81-Gamer
- 8GB HyperX FURY RAM
- 2GB NVIDIA® GeForce® GTX 960
- 120GB Kingston SSD
- 1TB Hard Drive
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- 3 Year Standard Warranty

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- ASUS® RoG MAXIMUS VII RANGER
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- 4GB NVIDIA® GeForce® GTX 970
- 120GB Kingston HyperX 3K SSD
- 2TB Hard Drive
- **Windows 8.1**
- 3 Years Warranty

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- 3 Years Warranty

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- 1TB Hard Drive
- **Windows 8.1**
- 3 Year Standard Warranty

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MICRO-ATX CASE

Phanteks Enthoo Mini XL / **£142** inc VAT (£165 inc VAT with ITX upgrade kit)SUPPLIER www.scan.co.uk

Phanteks makes some excellent full towers, but has only more recently turned to small form factors, although the confusingly named Mini XL is hardly small, with dimensions more akin to a large mid-tower. What this space offers you, however, isn't only heaps of water-cooling support, but also the ability to house a second, full mini-ITX system inside with the purchase of a £23 upgrade kit.

The weighty Mini XL is definitely costly, but you get lots of high-quality metal for the money. It's also aesthetically pleasing, with sand-blasted aluminium front and roof panels, and dual side windows. Meanwhile, its glossy trim section up and along the right houses LED strips, which can be toggled between one of ten colours using a button on the roof's I/O panel. You can also buy extra LED strips to add internally, which will match the external colour.

There's a vast number of fan mounts, most of which have elongated mounting holes, giving you some flexibility with regards to fan positions and radiator spacings. Three 140mm fans are supplied out of the box, and all intake areas are guarded by high-quality dust filters.

The side, front and roof panels all come away cleanly – you just need to disconnect the LED strip cable from the front panel. Modders will also appreciate the number of screws used – you won't need a drill to remove the steel roof panel or optical drive cage, for example.

In fact, the design is well thought out everywhere, and each piece of hardware is very simple to install. There's also plenty of room for CPU coolers and GPUs, while the five expansion slots mean that dual-slot cards can be used in the lowest slot of your micro-ATX motherboard.

For storage, there are two easily removable three-bay cages, along with two 2.5in brackets behind the motherboard tray, which can be relocated to be visible through the smaller window. You can also purchase extra 2.5in brackets, as well as 3.5in brackets (none is supplied) for mounting on the side and/or bottom of the optical drive cage.

The pre-routed, pre-connected cables are great too. Coupled with the Velcro cable ties, numerous routing holes with secure rubber grommets and ample space behind the motherboard, they make tidying the case a joy. The three fans come connected to the fantastic PWM fan hub, which will power and control the speed of up to 113-pin fans using just a SATA 12V connection and your motherboard's 4-pin CPU fan header – a great system for unified fan control and easy cable management alike.



All that space inside is good news for water cooling. There's 206mm of roof clearance for 280mm and 360mm radiators, which can also be installed along the floor, albeit with less clearance and the need to remove the lower hard drive cage. If you remove both cages, 280mm radiators are supported in the front, or 240mm radiators in the side (using the supplied bracket), with lots of space for thick setups. Even the rear can house a 240mm or 280mm model thanks to the dual fan mounts. Phanteks includes a pump bracket, with a thick rubber base to dampen vibrations, and a reservoir bracket. For a better idea of the Mini XL's flexibility, check out the video at <http://tinyurl.com/CPCMiniXL>.

The options don't end there either, as there's also the ITX Upgrade Kit. With this kit, you replace the rear panel then install a secondary motherboard tray and a 5.25in bay module with front panel ports and buttons. It's a fairly simple procedure, but a dual system isn't without issues.

For example, you lose support for 140mm fans in the rear, so we moved ours to the roof as an exhaust above the mini-ITX system's low-profile cooler. However, the ITX motherboard tray prevents 140mm fans from being properly used here, and we could only attach it on one side. Also, the second PSU must be an SFX model, and is installed on the floor, meaning it could easily conflict with your micro-ATX system's expansion cards and CPU cooler, especially if the latter is a tower model, as with ours. We also had to swap the PSUs, running the micro-ATX rig off the SFX PSU, due to cable-length limitations. You need to consider which PSU is responsible for the LEDs, fan hub and, if you're water-cooling, your pump too. Using two systems in one case is cool, but it definitely requires some planning.

/SPECIFICATIONS

Dimensions (mm) 260 x 480 x 550 (W x D x H)

Material Aluminium, steel

Available colours Black

Weight 7kg

Front panel Power, reset, LED toggle, 2 x USB 3, stereo, mic

Drive bays 3 x external 5.25in, 6 x internal 3.5in/2.5in, 2 x internal 2.5in

Form factor(s) 'Super Micro ATX' (micro-ATX, mini-ITX, micro-ATX + mini-ITX via optional ITX Upgrade Kit)

Cooling 2 x 140mm/120mm front fan mounts (2 x 140mm fans included), 2 x 140mm/120mm rear fan mounts (1 x 140mm fan included), 2 x 140mm or 3 x 120mm roof fan mounts, 2 x 140mm or 3 x 120mm bottom fan mounts, 2 x 140mm/120mm side fan mounts, 2 x 120mm internal HDD fan mounts (fans not included)

CPU cooler clearance 215mm

Maximum graphics card length 290mm (410mm without HDD cage)

Extras Removable dust filters, external RGB LED lighting, PWM fan hub, pump bracket, reservoir bracket, radiator bracket

1

The five expansion slots mean a dual-slot card can be used in the lowest slot



2

There are two easily removable three-bay hard drive cages on the right



3

There are numerous cable-routing holes, lined with rubber grommets

Performance

Cooling of the micro-ATX system is excellent. The lower section of the Mini XL has great front-to-back airflow, and both the CPU and GPU results are among the best we've seen, with the fans not spinning too loudly either. Adding the mini-ITX system to the thermal test at the same time has surprisingly little effect too; the CPU delta T increases by just 2°C, and although the GPU delta T goes up by 6°C, it's also battling the SFX PSU for air.

Mini-ITX cooling isn't great for the CPU, which gets pretty toasty, since it receives little cool air – it all seems to be sucked up by the graphics card, which actually does very well with a delta T of just 45°C; better than the Corsair 250D. However, turn on the micro-ATX system and it warms up by a massive 15°C, indicating that the larger system's CPU cooler is stealing most of the air from the ITX graphics card, leaving even less air for the CPU, the temperature of which goes up by another 10°C. In fairness, there's space for a larger CPU cooler than we used, but even so, the top part of the Mini XL is evidently a lot warmer than the bottom.

Conclusion

The Enthoo Mini XL is a unique case. If you can get all the power you need from a micro-ATX rig, then at £120 it would be a good match for a premium water-cooled system. It's



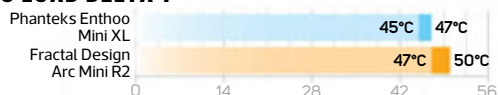
big, but an ATX machine with the same level of water-cooling support would require even more space.

Being able to house two systems, while niche, is a good deal for £165, and while the mini-ITX system became hot, we were running both systems overclocked and under full CPU and GPU load, and neither one throttled, which is impressive with just three fans. With a little forethought, you could use the Mini XL for many interesting projects.

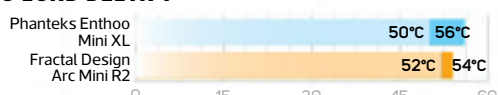
MATTHEW LAMBERT

MICRO-ATX RESULTS

CPU LOAD DELTA T



GPU LOAD DELTA T



Single system Dual system
Low fan speed High fan speed

MINI-ITX RESULTS

CPU LOAD DELTA T



GPU LOAD DELTA T



Single system Dual system
Lower is better

COOLING

26/30

DESIGN

26/30

FEATURES

20/20

VALUE

15/20

OVERALL SCORE

87%

VERDICT

It's definitely more XL than mini, but Phanteks' dual system chassis is an outstanding example of case design with heaps of options for premium systems.

GAMING LAPTOP

MSI GT80 2QE Titan SLI-023UK / £3,500 inc VAT

SUPPLIER www.saveonlaptops.co.uk

MSI's GT80 is the first laptop we've seen with a mechanical keyboard, and there's no quibbling with its pedigree thanks to Cherry MX Brown switches and SteelSeries design. The keyboard and touchpad have been hauled forwards to the front edge, with the touchpad on the right – a design change that helps the GT80 to mimic a more conventional desktop setup.

There's no compromise when it comes to keyboard quality – it's as snappy and solid as the best desktop units, which lifts it beyond every other gaming laptop. We became used to the single-height Return key and the right-hand Windows key, and you'll only be disappointed if you're not a fan of Cherry's Brown switches. Meanwhile, the smooth touchpad's two buttons are light and snappy, and the surface doubles as a numeric keypad – press a button and the numbers illuminate.

Moving the keyboard and mouse forwards also enables MSI to devote more space to cooling. It's a necessary change, as the GT80 has one of the beefiest laptop specifications we've seen: two Nvidia GeForce GTX 980M GPUs and an Intel Core i7-4980HQ.

The GTX 980M uses the same GM204 Maxwell core as Nvidia's top desktop parts, and has 1,536 stream processors – nearly as many as the desktop GTX 970. Its clock speed of 1,038MHz is a tad lower than that of the GTX 970, too, but it boosts to 1,127MHz. Nvidia produces the GTX 980M with 4GB or 8GB of GDDR5 memory, and MSI has chosen the beefier 8GB version for the GT80, for a total of 16GB.

The Core i7-4980HQ is Intel's most powerful mobile Haswell chip, with four 2.8GHz cores and a top Turbo speed of 4GHz – It's paired with a whopping 32GB of 1,600MHz DDR3 RAM. The storage is similarly super-charged – a RAID 0 array containing four 256GB Toshiba HG6 M.2 SSDs. They have a combined capacity of 952GB, but beware the lack of data security – RAID 0 isn't mirrored, and if one drive goes down, you lose all your data. There's a more conventional 1TB hard disk too.

Meanwhile, Gigabit Ethernet and dual-band 802.11ac Wi-Fi come from Killer, and there's Bluetooth 4 support too. The GT80's borders are versatile as well, offering five USB 3 ports, two mini-DisplayPort connectors, S/PDIF, an HDMI port, an SD card slot and a headphone jack. Two buttons lurk above the keyboard too – one to ramp up the fan speed and another to switch between integrated and discrete graphics.

The GT80 is sturdy and looks the part, with red lines and backlighting, but there's no escaping its sheer size. Its 4.5kg weight and 49mm thickness make it twice as bulky as many cheaper and admittedly slower machines, and it's so big that MSI includes



a bespoke backpack. Also included is a metal tin that contains five gold-coloured keys – four to replace the WASD buttons, and another for the Escape key – and there's a foam wrist rest and MSI-branded mouse mat too.

Remove the base panel and it's obvious why the GT80 is so large. The front half is dominated by the battery and keyboard, and the back is crammed with cooling hardware: the processor sits in the middle and is topped by two heatpipes, and the GPUs sit on raised daughterboards with heatpipes to chill the cores and memory.

The three main chips can be reached with a bit of elbow grease, and two memory slots are accessible, but that's about it – two more memory slots and the SSDs are on the other side of the motherboard.

We've one doubt though – whether anyone really needs the GT80 at all. It's heavy and unwieldy enough to ensure it's never leaving the mains for any length of time and, if that's the case, why not build a similarly specified mini-ITX desktop and save yourself several hundred pounds? Thankfully, there are more affordable SKUs. The 215UK includes a lesser Core i7 chip, one SSD, 16GB of memory and two GTX 970M GPUs for £1,999, while the 215UK maintains the two GTX 980Ms but cuts down the specs elsewhere for a revised price of £2,599. Given that the screen only has a 1080p resolution anyway, these cheaper versions will be more than capable.

Performance

There's no disputing the GT80's gaming ability. Its minimum of 92fps in Battlefield 4 is superb and, like the Dino PC Phoenix we reviewed last month, it doesn't even drop below 60fps in Crysis 3, maintaining a superb minimum of 68fps.

The rapid gaming performance was bolstered by good application results too. Its image editing score of 35,464 was strangely behind the 46,439 scored by the Dino PC, but it fought back with brilliant encoding and multi-tasking scores of 201,984 and 137,240, making for a cracking overall system score of 98,345. The high-end storage undeniably

/SPECIFICATIONS

CPU 2.8GHz Intel Core i7-4980HQ

Memory 32GB 1,600MHz DDR3

Graphics 2 x Nvidia GeForce GTX 980M

Sound On-board

Networking Gigabit Ethernet, 802.11ac Wi-Fi

Screen size 18.4in 1,920 x 1,080

Storage 4 x 256GB Toshiba HG6 M.2 SSDs in RAID 0, 1TB Hitachi hard disk, Blu-ray writer

Weight 4.5kg

Ports 5 x USB 3, Gigabit Ethernet, HDMI, 2 x mini-DisplayPort, optical S/PDIF, 1 x audio

Dimensions (mm) 456 x 330 x 49 (W x D x H)

Warranty Two years collect and return

helps. The quartet of RAID drives combined for sequential read and write speeds of 1,507MB/sec and 1,095MB/sec – it's just a shame that they also carry a large risk with them.

The hefty cooling gear helped the MSI to better thermal results than the Dino PC's temperature too. The processor's top temperature of 88°C was 9°C cooler than the Phoenix, and the GPUs topped out at 83°C – again, toasty but still cooler than the Dino PC. The chassis didn't overheat either, and the noise wasn't too bad. The fans do get loud, but the noise levels aren't uncomfortable.

Meanwhile, the screen's 1,920 x 1,080 resolution sensibly avoids the scaling issues that are sadly still prevalent with many Windows apps, but such a powerful laptop could handle a higher resolution with its two GPUs and 18.4in diagonal. The screen quality is great though. Its average delta E of 2.91 and colour temperature of 7,050K are both far better, and its contrast ratio of 1,086:1 is behind the Phoenix, but still excellent. The brightness of 391cd/m² and black level of 0.36cd/m² are both good, too. The MSI's screen isn't quite as dark as the Dino PC's panel, but it offers great brightness, contrast and depth, and better colour reproduction too.

The speakers are good too, providing a surprising amount of volume, rich bass, a crunchy middle, and a top end that's snappy and well-balanced. Not surprisingly, battery longevity isn't the MSI's wheelhouse. In a gaming test with the screen at 100 per cent brightness, the GT80 lasted for 63 minutes – longer than the Dino PC's 28 minutes, but not long enough to enable any serious play away from the mains.

Conclusion

There's no denying the speed available from the GT80 – it offers simply stunning gaming pace at the screen's native



resolution, as well as super-fast application performance and a great quality screen.

The ergonomics beat rivals too: the mechanical keyboard is excellent, and the right-hand touchpad is great. The price for the top spec, though, is far less palatable. Given that the graphics system is overkill for the screen's 1080p resolution, and the risk involved with a four-drive RAID 0 storage system, you'll get better value for money by plumping for one of the cheaper GT80 SKUs, still giving you the great chassis and screen, as well as enough gaming performance for the 1080p screen. However, as a luxury, niche product for gamers who take a 'money no object' approach to their hardware, the top-spec GT80 is still as good as it gets.

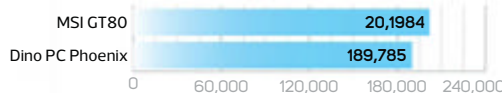
MIKE JENNINGS

- 1 A whopping 32GB of RAM is supplied with the top spec
- 2 The fans do get loud, but not uncomfortably so
- 3 The huge chassis measures 456mm across

CPC REALBENCH 2014 GIMP IMAGE EDITING



HANDBRAKE H.264 VIDEO ENCODING



LUXMARK OPENCL



HEAVY MULTI-TASKING



SYSTEM SCORE



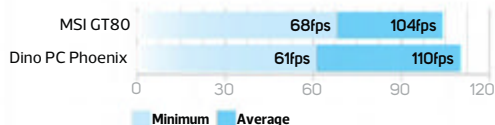
BATTLEFIELD 4

1,920 x 1,080, Ultra Detail, 4x AA



CRYSIS 3

1,920 x 1,080, Very High Detail, 0x AA



SPEED
25/25

HARDWARE
24/25

DESIGN
24/25

VALUE
13/25

OVERALL SCORE
86%


VERDICT

Incredible speed, high-quality ergonomics, a decent design and a top-notch screen, but the top spec version is just too expensive for most gamers to contemplate.

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GAMING KEYBOARD

SteelSeries Apex M800 / £160 inc VAT

SUPPLIER www.overclockers.co.uk

The keyboard market is saturated with Cherry MX switches, and we're seeing more companies move away from them in a bid to offer something different. SteelSeries is one such company, and its Apex M800 is fitted with a brand-new switch, the QS1. SteelSeries claims the M800 is the fastest available mechanical keyboard, and it offers per-key RGB backlighting and reprogramming for every key.

Unfortunately, build quality is a letdown – there's no look or feel of a premium keyboard, such as the Corsair K70 RGB, just a standard plastic chassis that picks up fingerprints quickly and is too easy to flex. At least there are decent rubber feet, which are swappable to increase the height.

The M800 features six dedicated macro keys, and a function key that can be used to control brightness, media and the Windows lock. There are also two USB 2 ports on the rear, both powered by the secondary USB connection; they're handy but a single USB 3 port would be preferable.

Replacement keycaps with Apple keyboard symbols are included too, but there's no key puller, nor is there a wrist rest, which feels stingy at this price.

Rated for 60 million clicks, the new QS1 switch is a joint effort by Kailh and SteelSeries. It has a square-shaped plunger with space for an RGB LED in the middle, unlike Cherry switches where

LEDs are top-mounted. The result is a more even backlighting, but the most striking aspect is the low profile – the linear switches have a total travel of just 3mm with a 1.5mm actuation point, 25 per cent shorter than a Cherry MX Red but with the same actuation force (45cN). The keycaps too are very short too – similar to what you'd find on a membrane keyboard.

The shorter actuation point is noticeable and the switches have a smooth action. Also, the keycaps' surfaces are aligned on a single plane, making it easy to glide fingers across them. The M800 really is fast, and it's easily the quietest mechanical keyboard we've used too.



The software we used was in beta, but it still impressed. Key bindings and illumination settings both use an intuitive key map, and multiple profiles are easy to set up and assign to programs. Your profiles can also be backed up to the cloud for access anywhere. The M800 can store one profile on-board too, but requires software to be running for macros and LED-based countdown timers to work.

Meanwhile, the lighting effects are complex; Corsair's software has yet more options, but SteelSeries' is by far the easier one to use. The M800 features active and idle modes, with the latter being a screensaver-style pattern that activates when the keyboard isn't in use. Key bindings include the usual functions, such as shortcuts to programs and profile switching, and practically every key can be remapped, not just the macro ones. Reprogramming is again very easy and the macro editor in particular is a joy to use. Regardless of your lighting patterns' complexity, the keyboard won't skip a beat – the M800 has n-key rollover and dual processors, with one CPU dedicated to handling key presses.

Conclusion

At £160, the M800 is one of the most expensive keyboards around. Developing a new switch is obviously costly and, to be fair, it's paid off; many people will appreciate the low profile, responsive keys and quietness. However, the QS1 switch needs to find its way into cheaper models to gain some ground. As it stands, the M800 is a feature-rich keyboard with good switches, but it's also let down by its plastic build quality for the price.

MATTHEW LAMBERT

The switches have a total travel of just 3mm

/SPECIFICATIONS**Connection** Wired, 2 x USB**Cable** 2m, braided**Material** Plastic**Switch type** SteelSeries QS1**Backlighting** RGB, per-key**USB ports** 2 x USB 2**Wrist rest** No**Extras** 6 x macro keys, n-key rollover, Windows lock, media keys**DESIGN**
38 / 45**FEATURES**
23 / 25**VALUE**
17 / 30**OVERALL SCORE**
78%**VERDICT**

Too expensive for the build quality, but the QS1 is a great new switch and we look forward to seeing how it's used elsewhere.

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GAMING HEADSET

HyperX Cloud II / £75 inc VAT

SUPPLIER www.ebuyer.com



ELITE
NEW ENTRY
P62

We're always cautious when a manufacturer updates one of our Elite-listed products. After all, the Elite list is a collection of the finest products on the market, and improving on any one is a tall order. Fortunately, the Cloud II seems to be merely a tweak to the already winning formula. Indeed, the only visible difference between the Cloud II and the original Cloud is that the former's cup arms have a red anodised finish rather than the black of the latter.

As such, the Cloud II retains the sturdy black leather headband, large circumaural ear cups and comfortable, leatherette-covered, memory foam-filled ear pads that made the Cloud a pleasure to wear during long gaming sessions. Inside, the large 53mm drivers are still present too, as is the detachable microphone. Even the bundle of extras remains the same, with a handy airplane adaptor, carry bag and an extra pair of microfibre-covered ear pads included in the box.

It's only by venturing away from the headset and looking at the cabling that that you see where HyperX has made its changes. Here, you'll find that the original Cloud's pair of two-conductor 3.5mm jacks have been amalgamated into a single 4-conductor 3.5mm jack. This means the Cloud II is far more comfortable being plugged into a smartphone or tablet, as there's no extra

jack cable dangling, and you can use the microphone if you wish. On the negative side, the headset now plays much less nicely with traditional PC sound cards, which tend to require microphone audio delivered over a separate jack (as with the original Cloud).

To skirt this issue, HyperX has turned the Cloud II into a USB headset (via a 1m extension cable), with a dedicated sound card now integrated into the Cloud II's in-line remote. This particular setup won't please everyone (especially people with discrete sound cards) but it does make for a more flexible headset.

As a sweetener, the in-line sound card boasts an optional emulated 7.1 surround mode. Opinion on this mode was mixed at best – some in the team liked the extra sense of space it lent audio, particularly in games, whereas others felt that the default stereo audio was cleaner and better balanced.

Thankfully, with the 7.1 surround mode off, the audio output of the Cloud II was all but indistinguishable from that of the Cloud, despite the change in connection. Bass was still deep

and booming, the mid-range was still beautifully balanced and high frequencies were still picked out in a way that no other gaming headset seems to be able to manage.

The redesigned in-line remote was also much more pleasant to use than that of the original Cloud, as it now features a clip, to keep it just where you need it, and the buttons are much bigger (despite the remote itself being smaller).

Conclusion

The Cloud II is an excellent headset – the audio, build quality and extras bundle are all top class, while the tweaks made to the connections of the headset will benefit most people. The 7.1 surround mode won't suit everybody, but it's easily ignored if you don't like it. If you're in the market for a new headset and are comfortable with it connecting via USB, the Cloud II should be at the top of your list.

PAUL GOODHEAD



A dedicated sound card is now integrated into the in-line remote

/SPECIFICATIONS

Cup type Circumaural

Connection Wired, single 3.5mm jack, USB extension cable with in line remote

Driver(s) 53mm

Frequency response 15Hz to 25KHz

Impedance 60 Ohms

SOUND
36/40

DESIGN
29/30

VALUE
23/30

OVERALL SCORE
88%

VERDICT

The new connections make the Cloud II more flexible, while retaining the original Cloud's excellent audio and build quality.

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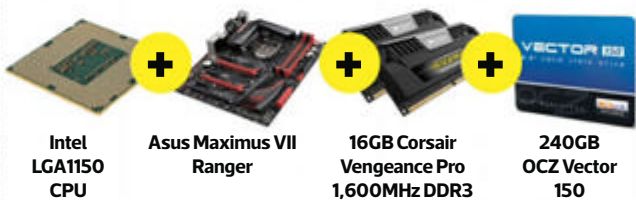
How we test

Thorough testing and research is the key to evaluating whether a product is worth buying, and deciding whether or not there's a better alternative

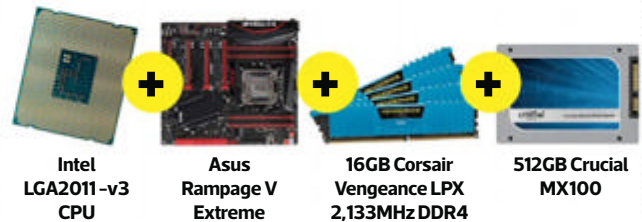
PROCESSORS

We judge CPUs on whether they offer sufficient speed for the price. Part of a CPU's speed score comes from how overclockable it is. Every type of CPU is tested in the same PC, so all results are directly comparable.

INTEL LGA1150



INTEL LGA2011-V3



AMD FM2+



COMMON COMPONENTS

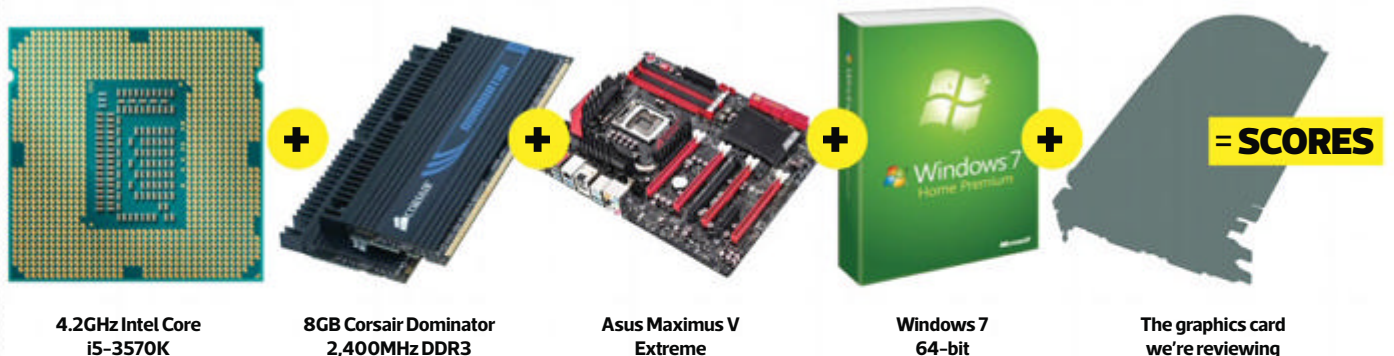


TESTS: We use the Custom PC Media Benchmarks (or CPC RealBench 2014 on LGA2011-V3), Cinebench R11.5 and a variety of games. We also test the power draw of the test PC with the CPU installed. These tests reveal a broad range of performance characteristics, from image editing to gaming and video encoding to 3D rendering. We run all tests at stock speed and again when overclocked to its highest frequency.

*Please note: We test AMD FM2+ APUs using the on-board graphics, not the Nvidia GeForce GTX 780 3GB

GRAPHICS CARDS

Graphics cards are mainly evaluated on how fast they are for their price. However, we also consider the efficacy and quietness of the cooler. Every graphics card is tested in the same PC, so all results are directly comparable.



CUSTOM PC MEDIA BENCHMARKS



2.66GHz Intel Core 2
Duo E6750



2GB of Corsair
1,066MHz DDR2



250GB Samsung
SpinPoint P120S



Asus P5K Deluxe WiFi-AP

=1,000

Our benchmark suite simulates how people really use PCs, and a higher score is better. You can download the suite from <http://tinyurl.com/CPCbenchies>

MOTHERBOARDS

Motherboards are evaluated on everything from layout and features to overclockability and value for money. Every motherboard is tested with the same components, so all results are directly comparable.

INTEL LGA1150



Intel Core i7-4790K Motherboard on test 16GB Corsair Vengeance Pro 1,600MHz DDR3 240GB OCZ Vector 150

INTEL LGA2011-V3



Intel Core i7-5960X Motherboard on test Plextor M6 256GB 32GB Crucial 2,133MHz DDR4

AMD FM2+



AMD A10-7850K Motherboard on test 16GB Corsair Vengeance Pro 2,133MHz DDR3

COMMON COMPONENTS



Nvidia GeForce GTX 780 3GB* Windows 7 64-bit

TESTS: We use the Custom PC Media Benchmarks (or CPC RealBench 2014 on LGA2011-V3) and several games, and also test the speeds of the board's SATA ports. We try to overclock every motherboard we review by testing for a maximum QPI, base clock or HTT as well as overclocking the CPU to its maximum air-cooled level. We run our tests at stock speed and with the CPU overclocked.

*Please note: We test AMD FM2+ motherboards using the on-board graphics, not the Nvidia GeForce GTX 780 3GB



TESTS: By using the fast PC detailed on the left, we can be sure that any limitations are due to the graphics card on test, rather than being CPU limited. We test the four games (above) at their maximum detail settings, in their highest DirectX mode, at several resolutions. High-end cards should be able to sustain playable frame rates at 2,560 x 1,440, while 1,920 x 1,080 is more important for mid-range cards; we also test at 3,840 x 2,160 for 4K monitors, and try to overclock every graphics card we test to assess the performance impact.

The Awards



EXTREME ULTRA

Some products are gloriously over the top. These items of excellent overclock earn our Extreme Ultra award.



PREMIUM GRADE

Premium Grade products are utterly desirable – we'd eat nothing but beans until we could afford them.



PROFESSIONAL

Products worthy of the Professional award make you and your business appear even more awesome.



APPROVED

Approved products are those that do a great job for the money; they're the canny purchase for a great PC.



CUSTOM KIT

For those gadgets and gizmos that really impress us, or that we can't live without, there's the Custom Kit award.

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- STEP 4** Enter your *Apple ID* password to confirm



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Custom Kit

Paul Goodhead checks out the latest gadgets, gizmos and geek toys

MOUSE MAT

HyperX Skyn (Speed + Control) / £14 inc VAT

The HyperX Skyn mouse mats come as a pair, with one smooth 'speed' surface mat and one textured 'control' mat in each pack. Paper-thin and secured to a desk via an adhesive backing, they aren't like any mouse mats we've seen before. Use the mats for a few days, though, and you begin to see HyperX's thinking – there aren't any edges to catch, and they're so thin they feel like they're built into the desk. The adhesive keeps them rock steady too, and it isn't permanent, so the mats can be peeled off and relocated multiple times (although not indefinitely). We preferred the control mat, as we found our hand getting sweaty when resting on the smooth speed mat, but both worked well, and at £14, they're affordable too.

SKINT ●●●●● **SKIN**

SUPPLIER www.cclonline.com



HEADPHONES

Arctic P614BT / £34 inc VAT

Arctic isn't necessarily a brand you'd immediately think of if you were looking for a set of Bluetooth headphones, but the P614BTs are well worth considering for £34. They feel well built and sturdy, and pairing the headphones to our test phone was a cinch. Audio is meaty and rich, with good, rounded bass frequencies and a solid mid-range.

The high frequencies lacked a little, but not enough to spoil the otherwise satisfying mix. The unit includes a carry case too. The only negative is that the P614BTs lack a backup audio connection – it's Bluetooth or nothing, so they're dead weight if their battery runs out. Even so, they offer good value for money and good quality – you just need to remember to keep them charged.

POLAR VORTEX ●●●●● **SNOW DAY**

SUPPLIER www.amazon.co.uk



BOARD GAME

Monopoly World of Warcraft Collector's Edition / £30 inc VAT

The special edition Monopoly trail is pretty well trodden, but we couldn't help ourselves when we saw the World of Warcraft Collector's Edition. Bedecked in lovely artwork, the core rules and mechanics are the same as those in the classic game, but everything else is WoW themed to the nth degree. There are custom playing pieces (which were voted for by the WoW community), new house and hotel markers, and all the locations are Azeroth based (Orgrimmar and Stormwind replace Mayfair and Park Lane if you were wondering).

The only missed opportunity is that the game still uses paper money (albeit redesigned) – surely it's only right to push around huge piles of gold while building a WoW property empire?

CORPSE CAMPED ●●●●● **POSTMASTER EPICS**

SUPPLIER www.rakuten.co.uk





LAPTOP SPEAKER

Microlab B51/£9 inc VAT

The Microlab B51 speaker is around the size of a TV remote, and it's designed to clip onto the top edge of a laptop screen, upgrading the invariably awful built-in speakers. A USB connection provides power, while audio is handled via a 3.5mm jack.

The audio quality is perfectly acceptable too, as long as you don't push it past 60 per cent volume. It's a decidedly low-fi system, although it would be much cleaner to get audio via the USB cable,

or even via Bluetooth – but this lack of sophistication is reflected in the bargain basement price.

There's only one catch, which is that it's heavy for its size, to the point where the extra weight would drag down our laptop screen if it wasn't perfectly balanced, which is annoying.

MICRO MEAL ●●●●● **MICRO MACHINES**

SUPPLIER www.ebuyer.com



PINHOLE CAMERA

VIDDY/£38 inc VAT

If you think pinhole cameras are rickety affairs assembled in secondary school classrooms then think again. Made from thick die-cut cardboard, the VIDDY takes around 40 minutes to assemble and feels reassuringly solid once complete. There isn't any overly fiddly sticking or cutting, and it's all clearly marked out, meaning it's a task that can easily be shared with a child. Once made, the camera takes 35mm or medium-format film, and while results can be a little on the rustic side, there's a certain joy to having to consider factors such as exposure time and getting your film developed. It's obviously no replacement for a conventional camera, but it makes an ideal fun project or gift. Just don't take it out in the rain.

SPEED CAMERA ●●●●● **PINHOLE CAMERA**

SUPPLIER www.prezzybox.com



BLUETOOTH SPEAKER

LAVA BrightSounds/£40 inc VAT

Putting an LED in a Bluetooth speaker may seem bizarre, but for keen campers or festival goers, the BrightSounds is a fantastic gadget. The speaker, which makes up the top third of the device, handled our test tracks well with only the barest smidge of distortion at its very loud full volume. The dimmable light was bright and consistent too, and a rubber strap makes it easy to hang or carry the BrightSounds.

It's ruggedised and water-resistant, so it will cope with life outdoors and, at £40, it offers good value for money too. Our only slight nit-pick is battery life – the battery is rated for eight hours of audio or ten hours of light, but it runs down quicker if you use both together. We'd love to see a larger version with a bigger battery.

PALAUER ●●●●● **LAVA**

SUPPLIER www.amazon.co.uk

Seen something worthy of appearing in Custom Kit? Send your suggestions to paul_goodhead@dennis.co.uk



LABS TEST

Solid state of bliss

With plummeting prices and swelling capacities, there's never been a better time to jump on the solid state party truck. We put over 20 drives through their paces to find the ones that deserve your cash

We now consider a solid state drive an essential part of any PC build, with the performance difference between an SSD and a mechanical hard drive being much greater than the difference between CPU upgrades in terms of system responsiveness. Although you pay more money per gigabyte for flash-based storage than you would with a hard disk, the significant boost to performance is worth the outlay. SSD prices have dropped significantly since we last looked at them in the Labs (see Issue 128, p40) too. You can now buy a 256GB drive for under £70, which is a comfortable size for Windows and applications, with larger capacities now being much more affordable as well.

Performance is generally improving too, with even entry-level models offering speeds well in excess of even the fastest hard disks. It's also safe to say that flash cell endurance is no longer an issue for the most part, unless you actively seek to destroy an SSD.

If you haven't invested in a solid state drive yet, the falling prices and larger capacities mean it's now a better time than ever to jump on board. What's more, if you were an early adopter, and you're still using an old 64GB or 128GB SSD, a cheap upgrade will now mean more fast flash-based storage and better overall system performance too.

MATTHEW LAMBERT AND ORESTIS BASTOUNIS

Featured this issue

How we test / p41

Crucial MX200 250GB, 500GB and 1TB / p42

Crucial BX100 250GB, 500GB and 1TB / p43

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SanDisk Extreme Pro 480GB / p48

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Samsung 850 EVO 250GB, 500GB and 1TB / p51

Samsung SSD 850 Pro 256GB, 512GB and 1TB / p52

Results / p54

How we test

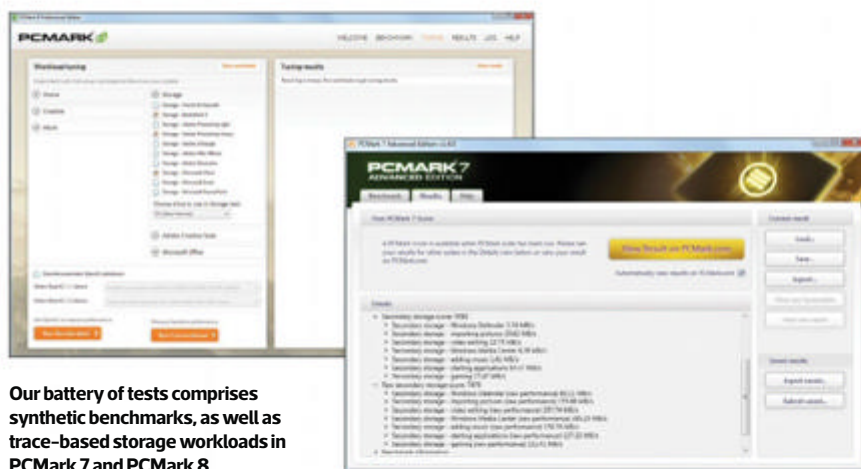
There are many facets of SSD performance that can be assessed. Our own battery of tests comprises synthetic benchmarks, trace-based storage workloads in PCMark 7 and PCMark 8, a boot time measurement and Iometer's I/O workload generator. Prior to testing, we issue an ATA Secure Erase command to each drive using the SSD's software package if available, or with the Parted Magic (www.partedmagic.com) Linux build if not.

This procedure tells the controller to release all stored electrons within every NAND module, erasing all data and resetting the SSD to factory performance.

For synthetic tests, we use the free storage benchmarks AS SSD (<http://tinyurl.com/ASSSDCPC>) and CrystalDiskMark (tinyurl.com/CPCCDM), which enable you to easily compare your own PC's storage performance against the drives on test. Both benchmarks perform a theoretical test of a drive's sequential read and write performance, as well as its 4KB random read and write performance, both at single and high queue depths (64-queue-depth in AS SSD; 32-queue-depth in CrystalDiskMark). While the two tests are similar, they use slightly different data patterns, so performance between them can vary. AS SSD automatically does multiple runs and reports the average, while we set CrystalDiskMark to use the 1,000MB file size on five runs, and we again report the average.

For real-world testing, we first use PCMark 7's Secondary Storage benchmark, which loops three times and averages itself. It uses recorded SATA traces (the exact traffic over the SATA bus at the time of recording) to simulate performance in seven different ways, including using Windows programs, importing pictures and music, video editing and gaming. It then generates an overall score based on the time taken to complete the tests, which we report. Note that the traces (and the score) include idle disk activity time, as with real-world use.

We've also added PCMark 8 to the real-world mix, which again uses traces, but with more recent software. In this case, we've selected the Photoshop Heavy, Battlefield 3



Our battery of tests comprises synthetic benchmarks, as well as trace-based storage workloads in PCMark 7 and PCMark 8

and Microsoft Word tests, with the results being the time taken to complete the traces.

We also test how long each drive takes to boot a clean Windows 7 64-bit installation using the freely available BootRacer (www.greatis.com/bootracer), which measures boot times down to a thousandth of a second. This test is performed using a SATA 6Gbps port on a Gigabyte Z97X-UD5H with an Intel Core i7-4790K and 4GB of 1,600MHz Crucial Ballistix DDR3 RAM. The system also uses an XFX Radeon R9 280 graphics card. We install the 14.12 Catalyst drivers and reboot the system five times to allow Windows to get its caching in order, before taking the average of the five subsequent boot times.

Our final test uses the free Iometer tool (<http://tinyurl.com/CPClometer>). With it, we generate four 64-queue-depth workload patterns (Database, File Server, Workstation and Web Server) designed to simulate heavy use scenarios using different file sizes and write-to-read ratios. We run each test for five minutes using fully

	Read [MB/s]	Write [MB/s]
All	546.6	517.4
Seq	546.6	517.4
812K	310.1	476.9
4K	39.34	124.1
4K QD32	401.5	363.8

random data – easily enough to stress test a modern SSD controller. The number reported is the average IOPS (input/output operations per second) of all four tests.

This test is performed on the drives as raw, unformatted volumes (a requirement of Iometer).

All tests other than BootRacer are performed on an Asus Maximus V Extreme's SATA 6Gbps ports, using an Intel Core i5-3570K and 8GB of 2,400MHz Corsair Dominator DDR3 RAM. **ML**

THE SCORES

The Speed score is taken from a weighted breakdown of the performance tests. AS SSD and CrystalDiskMark account for 15 per cent each, while 60 per cent is allocated to the PCMark 7, PCMark 8 and BootRacer real-world tests; these tests have the highest weighting since they're the most relevant for everyday use. The final 10 per cent comes from Iometer, as the sustained high-queue-depth workloads are only applicable to the most hardcore users. The price per gigabyte score is then based on the pricing at the time of writing over the accessible formatted capacity, while the bang/buck score is essentially a ratio of the speed and price per gigabyte metrics.

Crucial MX200 250GB, 500GB and 1TB

Crucial MX200 250GB / **£88** inc VAT

SUPPLIER www.cclonline.com

Crucial MX200 500GB / **£164** inc VAT

SUPPLIER www.cclonline.com

Crucial MX200 1TB / **£335** inc VAT

SUPPLIER www.scan.co.uk



Crucial's MX100 made a big impact when it launched in 2014, as it performed brilliantly while also being affordable. A few additions have since been made to its successor, the MX200, which have pushed up the price slightly, as the BX100 now occupies the role of Crucial's most budget-friendly SSD range. The 128GB capacity has been dropped and a 1TB version added. It uses the same Marvell 88SS9189 controller and 16nm Micron MLC NAND as before, though, and retains most of the extra features such as hardware-accelerated AES 256-bit hardware encryption.

Meanwhile, dynamic SLC caching is an interesting new addition for the 250GB model, christened Dynamic Write Acceleration by Crucial, with a portion of the available space reserved as SLC NAND for improved performance. But unlike other firms' fixed-size implementations of this idea, the cache on the MX200 grows and shrinks depending on usage. This feature isn't necessary on the 500GB and 1TB models, though, where it's been left out.

Quoted endurance is up drastically too, from 72TB of writes over five years, to 80TB for the 250GB model, 160TB for the 500GB and 320TB for the 1TB MX200, but Crucial is still only offering a three-year warranty, considerably less than SanDisk and Samsung's ten years on the 850 Pro and SanDisk Extreme Pro. The MX200 is also available in mSATA, 2260 (60mm) and 2280 (80mm) M.2 variants, although the 1TB capacity is only offered in the traditional 2.5in SATA version.

While the MX200 isn't quite the bargain of its predecessor, the larger capacities still offer reasonable value for money, working out at 35p and 36p per gigabyte on the 500GB and 1TB drives. You're getting much better professional-level performance from these two larger drives too, with IOPS results from the Iometer test only beaten by Samsung's pricier 850 Pro and Plextor's 512GB M6 Pro.

The MX200 does similarly well in both AS SSD and CrystalDiskMark's 4K random write tests, topping every other SSD model except Samsung's, a superb result for an SSD that

The MX200's cache grows and shrinks, depending on usage

offers good value for money. It notably drops off considerably in the read tests though – the 1TB MX200 was close to the bottom of the pack in the 32-queue-depth test, with just 271.3 MB/sec compared to the 1TB Samsung 850 Pro's 409.4 MB/sec.

In PCMark 8's traces of real-world applications, the MX200 is by no means the fastest SSD we've seen though. All three capacities are between one and two seconds slower in the Battlefield 3 trace load times than the Samsung 850 EVO models, sitting near the bottom of the table.

As we've stressed before, though, these differences are relatively slim, and are unlikely to be particularly noticeable in real-world use. The MX200 again scores towards the bottom in the Microsoft Word test, but the difference is just 0.3 seconds, so nothing to worry about. In BootRacer, once again the 1TB drive took the longest to load Windows at 12.02 seconds, but the 250B model edges ahead, taking 11.08 seconds, even beating the Samsung SSD 850 Pro 250GB.

Conclusion

If you want an affordable drive, Crucial's BX100 is a slightly better buy, offering great performance at a lower price than the MX200. Meanwhile, if you want a mid-range drive with more features, the Samsung 850 EVO eclipses the MX200, leaving the latter in a tight spot. The MX200 has more features than the BX100, such as hardware encryption, but these features aren't needed by most consumer desktop users, and aren't a reason for a recommendation alone. The MX200 range won't disappoint, but you can get a slightly better balance of performance and value for money elsewhere. **OB**

VERDICT

Decent speed and a solid feature set, but you can get a slightly better balance of performance and value elsewhere.

CRUCIAL MX200 250GB



CRUCIAL MX200 500GB



CRUCIAL MX200 1TB



Crucial BX100 250GB, 500GB and 1TB

Crucial BX100 250GB / **£74** inc VAT

SUPPLIER www.ebuyer.com

Crucial BX100 500GB / **£140** inc VAT

SUPPLIER www.dabs.com

Crucial BX100 1TB / **£282** inc VAT

SUPPLIER www.ebuyer.com



Following on from the roaring MX100, Crucial's new strategy is to split its low-priced SSD range in two. The more advanced MX200 has hardware-based encryption, a power-loss protection circuit and SLC caching for some impressive endurance figures, at a slightly higher price than its predecessor, while the BX100 drops these features and retains the MX100's great value.

It's based on Silicon Motion's new SM2246EN controller, and it's the first SSD to do so with custom-designed firmware. Unlike the MX200, Crucial hasn't bothered with M.2 or mSATA variants this time, sticking to the traditional 2.5in SATA format only, but it's also moved to four storage tiers, ranging from 120GB to 1TB.

Quoted endurance is identical to the MX100, with 72TB of writes across the board, which is to be expected, given the BX100's use of identical 16nm Micron MLC NAND, laid out in 128Gb chips.

Pricing is in the same low ballpark too, although the 250GB BX100 costs 32p per gigabyte, slightly more than the 31p offered by Kingston's SSDNow V300 SSD 240GB, while the larger 500GB and 1TB drives drop to a phenomenal 30p, the lowest of all the SSDs on test. What really made the MX100 special was that, despite its low price, it didn't make serious performance compromises. In both our synthetic and real-world tests, the BX100 retains this key characteristic.

It even comes close to the top of the chart in CrystalDiskMark's sequential read test, with all three capacities topping 550MB/sec,

beaten only by Samsung's SSD 850 Pro. AS SSD shows similar figures, with the 500GB BX100 coming in second place at 528.7MB/sec. The range drops slightly on sequential write speeds, though, with the 250GB model near to the bottom of the pack, managing 364MB/sec in AS SSD. Random read and write results aren't

The 500GB and 1TB drives cost just 30p per gigabyte, the lowest of all the SSDs on test

spectacular either, although interestingly, the 250GB BX100 fares best in these tests.

The IOPS results are interesting too. The BX100 is slap bang in the middle of the chart, with the 250GB model on 34,948 and the 1TB drive getting 37,941. The difference between the top-performing SSD 850 Pro and the BX100 is around 25 per cent in this test, which isn't bad considering that the BX100 costs around half the 850 Pro's price.

However, in the all-important real-world tests, you can easily see the true value of the BX100 range. All three capacities are closer to the top of the chart than the bottom in the

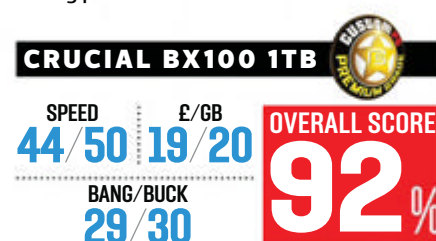
Photoshop Heavy and Microsoft Word tests, the BootRacer times for the 250GB and 500GB models are great (none of the 1TB drives did well here) and the Battlefield 3 trace is only one second slower than the top-scoring SSDs. With the BX100, you don't compromise on any real-world performance, but you pay the lowest price per gigabyte of any of the SSDs in this Labs.

Conclusion

The BX100s aren't the very fastest drives around, and Crucial even states this fact on its website. Clearly, in terms of sequential speeds, there's a gap between the BX100 and some pricier SSDs. But this gap seriously narrows in real-world performance, to the point where it would be hard to spot the difference between this drive and other, more expensive ones in general use. If you're looking for great performance for a low price, the BX100 range delivers in spades, with the 500GB and 1TB drives hitting the bang per buck sweet spot. **OB**

VERDICT

Fantastic performance for a surprisingly low asking price.



OCZ Arc 100 240GB / £76 inc VAT

SUPPLIER www.cclonline.com

The Arc 100's name is a logical continuation of OCZ's geometric nomenclature for its storage products, joining the Vertex 460 and Vector 150. It's the most affordable of the three, featuring the same Indilinx Barefoot 3 M10 controller, but running at a lower clock speed. It uses some slightly different Toshiba NAND as well, dubbed A19nm MLC flash, reflecting slightly lower-quality bins, helping it to hit one of the lowest price points in this Labs, just above the Crucial BX100 250GB.

In synthetic tests, the 240GB Arc 100 doesn't seem great. It had the lowest sequential read speeds in AS SSD and CrystalDiskMark, of 464MB/sec and 441.8MB/sec respectively. It fared a little better with sequential write speeds, but there's a wide gap between its 425.7MB/sec write in CrystalDiskMark and the 518.5MB/sec from Samsung's 250GB 850 Evo.

Likewise, in the random 4K tests, there's a considerable gap between the Arc 100 and

the best-performing SSDs, particularly in the read tests again. In AS SSD, its 27.2MB/sec result is close to the bottom of the pack. But real-world performance is where it matters, and that's where the 240GB Arc 100 picks up, completing the PCMark 8 Photoshop Heavy trace in 359.4 seconds, one of the fastest times.

The gaps between all the drives in the trace results are quite narrow, a fraction of a second in some cases, with the Arc 100 nowhere near the bottom. So for 34p per gigabyte, you're getting quite reasonable bang per buck. Although its synthetic test results look bad, the Arc 100 offers good real-world performance at a reasonable price. Its only problem is that the cheaper 250GB Crucial BX100 offers a slightly better deal. **OB**



VERDICT

Good real-world performance at a reasonable price, but it can't quite catch the Crucial BX100.



Kingston SSDNow V300 240GB / £70 inc VAT

SUPPLIER www.cclonline.com

The Kingston SSDNow V300 has been on the market longer than any of the other SSDs on test, being released back in 2013 and based on SandForce's aging SF-2281 controller. It's joined by Toshiba 19nm MLC NAND chips, which are built on 64Gb packages, while the warranty is pegged at three years,

which is typical of entry-level SSDs

However, the knock-on effect of the V300's maturity is a very low price. At 31p per gigabyte, only Crucial's larger BX100 drives offer a cheaper cost per gigabyte. As with the OCZ Arc 100 (above), the V300 doesn't handle synthetic tests well, languishing at the bottom of the charts for sequential write

speeds, managing just 226.2MB/sec in CrystalDiskMark and 217.4MB/sec in AS SSD. It's right at the bottom for 4KB random reads in AS SSD as well, with its 19.4MB/sec speed being less than half the 44.6MB/sec from Samsung's 850 Evo, and 50 per cent less than Crucial's BX100.

But the real-world performance traces in

PCMark 8 tell a different story; with a V300 you'll still enjoy all the usual benefits of an SSD. Windows boots in just 11.54 seconds, which is far better than even the fastest hard disk, and while the V300 is towards the bottom of the charts in the Photoshop Heavy and Microsoft Word tests, the differences between the fastest drives and the V300 are less dramatic in real-world tests.

However, the 250GB Crucial BX100 costs just £4 more, and offers better performance. The V300 isn't bad for the money – it's just up against stiff competition. **OB**

VERDICT

Fine as an entry-level drive, but Crucial's BX100 offers more bang for your buck.



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M.2 SSDs

We take a look at the next-generation SSD form factor

You could be forgiven for not knowing a great deal about M.2, since the term and the technology have only been around a short while. Originally known as NGFF, or next-generation form factor, M.2 is a 67-pin connector that's intended to replace the growing plethora of different standards for connecting storage devices and other peripherals to a motherboard. It's included on some Z97 and X99 motherboards, and it's starting to show up in a growing number of laptops too.

It works as an interface for a number of buses, including SATA, PCI-E, DisplayPort and USB. M.2 could eventually replace all these buses with one unified connector, overcoming the 6Gb/sec limit of the traditional SATA bus, which is a serious restriction on SSD performance. M.2 storage devices aren't necessarily faster than 2.5in SATA drives though. In fact, it's possible that a SATA-based M.2 SSD may even be slower than a top-end 2.5in drive.

However, PCI-E via M.2 works in exactly the same way as with a full-sized or half-height expansion card. There's 500 MB/sec of bandwidth per lane, and either two (2x) or four (4x) lanes can be used, for a maximum of 2GB/sec – quite an improvement over the 750MB/sec limit of the SATA 6Gbps bus.

For storage, one of the most attractive properties of M.2-compliant SSDs is the small dimensions of the PCBs. In ultra-thin laptops, even a 7mm-high 2.5in SSD can take up a large chunk of the available area, when all that's really needed is space for a few flash chips and the controller. And while full-sized PCI-E SSDs are fast, their reliance on an expansion card form factor limits them to desktop PCs, which can make them less of a worthwhile investment. You can't use an old



PCI-E SSD to upgrade a laptop further down the line, for example.

But M.2 isn't just limited to flash-based storage devices. Wireless add-in cards, NFC and digital radio adaptors are theoretically supported by the standard too, and it's possible this list of devices could grow in the future.

Different dimensions

M.2 cards are paired with a four-digit number that specifies their dimensions. The first two digits refer to the width (in millimetres) while the last two (or three) digits specify the card's length. So, for example, a 2260 card is 22mm wide and 60mm long. Another nuance of M.2 is the keying system used to define which bus a device supports, or a host accepts.

Of the 67 pins, a notch, or pair of notches, physically prevents certain cards from fitting into certain slots. A SATA M.2 SSD has the notch in a different place from a 4x PCI-E M.2 card, while a 2x PCI-E M.2 card is different again. Although this system may sound unnecessarily complicated, it allows for future expansion and upgrading as buses change. If a new standard is needed, another notch type can be created.

Protocols

M.2 SSDs can use either AHCI or the newer NVMe (Non-Volatile Memory Express) host-side protocols. AHCI was invented when hard disks were the only option for a system drive, so the protocol assumes it will have to wait for a platter to spin up when requesting data. It also came from an era of single-core



Crucial's M.2 MX200 SSDs come in both 60mm and 80mm lengths



Kingston's 4x PCI-E Predator HyperX is quoted as being capable of 1,400MB/sec read and 1,000MB/sec write speeds of compressible data

until the number of M.2 hosts (and potential customers) is reached. The same is true for NVMe; until more devices can boot SSDs that use this protocol, it's unlikely we'll see it show up in many SSDs.

In the meantime, manufacturers are getting creative with

their products. Kingston just launched the Predator HyperX SSD, a 4x PCI-E M.2 2280 (80mm) SSD, which it quotes as being capable of 1,400MB/sec read and 1,000MB/sec write speeds for compressible data, with 1,100MB/sec read and 910MB/sec write speeds of compressible data. Kingston neatly sidesteps many of the compatibility issues by bundling it with a half-height, half-length PCI-E card, so it can be used with your desktop computer even if it doesn't have an M.2 connector – an idea also used by Plextor. Meanwhile, NVMe has been eschewed in favour of AHCI, to ensure compatibility. **08**

processors, so it makes little use of parallelism. For example, the maximum queue depth is only 32 with AHCI.

NVMe, however, is a protocol for the modern era of multi-core computing and storage devices, with latency times that are thousands of times shorter than hard disks. It extends the maximum queue depth to 65,536, increases the number of interrupts and relaxes locking rules for synchronised issuing of commands. The changes in NVMe allow for much faster storage performance.

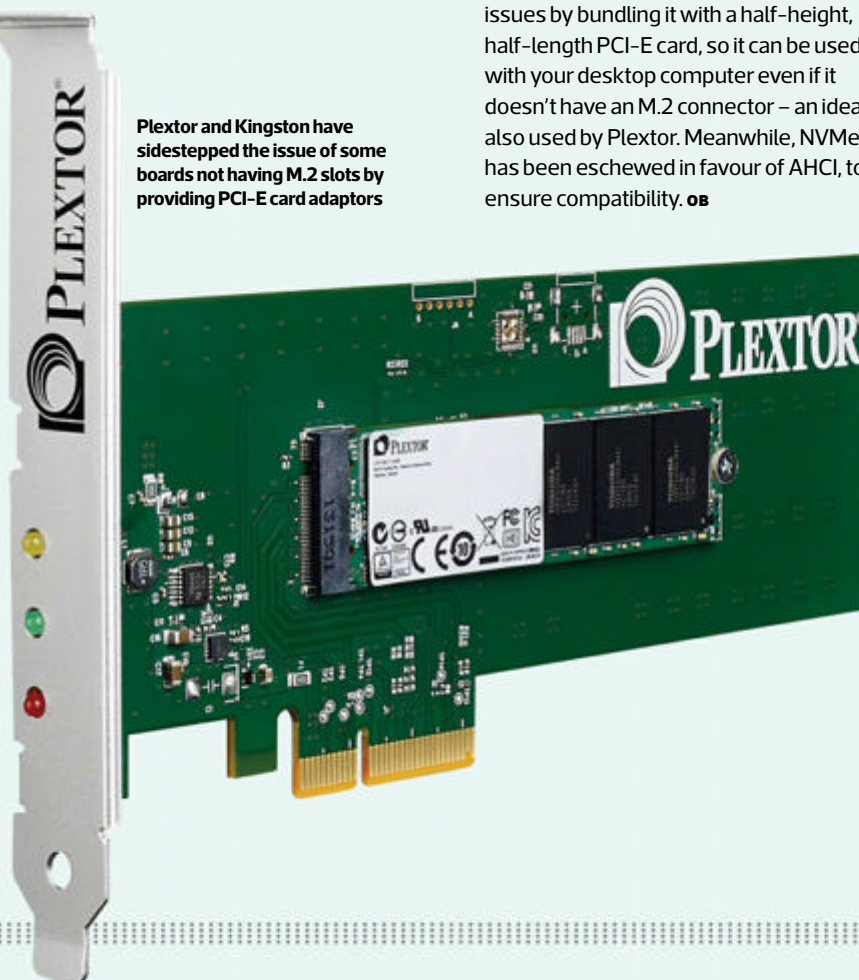
AHCI is unlikely to disappear immediately though. Just about every motherboard from the last decade can boot AHCI devices, while NVMe needs specific support in the BIOS/EFI. However, you can expect all desktop Broadwell systems to support booting from PCI-E NVMe devices.

Devices

There aren't many M.2 devices around at the moment, and many of the M.2 SSDs currently on the market use the SATA bus, so the only advantage they offer is a smaller form factor. This situation is certain to change very soon, though, and we expect to see a growing number of available devices this year. Nevertheless, the transition from SATA to M.2 as the storage connector of choice will take time.

The vast majority of computers around the world have SATA ports, while only a tiny fraction currently support M.2. For manufacturers, it makes more sense to continue to support SATA for the time being,

Plextor and Kingston have sidestepped the issue of some boards not having M.2 slots by providing PCI-E card adaptors



Plextor M6 Pro 256GB and 512GB; SanDisk Extreme Pro 480GB

Plextor M6 Pro 256GB / **£125** inc VAT

SUPPLIER www.scan.co.uk

Plextor M6 Pro 512GB / **£234** inc VAT

SUPPLIER www.cclonline.com

SanDisk Extreme Pro 480GB / **£212** inc VAT

SUPPLIER www.amazon.co.uk



The Plextor M6 Pro and SanDisk Extreme Pro occupy the same space in this Labs, as they share the same controller, Marvell's 88SS9187. They differ in the types of NAND used, though, along with the features on offer, with both firms offering their own tweaks and proprietary additions. The Extreme Pro uses SanDisk's own 19nm 2-bit NAND, with Plextor instead opting for A19nm Toshiba MLC NAND as used in the OCZ Arc 100.

The M6 Pro comes in four capacities, from 128GB to 1TB. Plextor has added a generously sized cache to each drive, with 256MB of DDR3 in the 128GB model, 512MB in the 256GB, 768MB in the 512GB and 1GB in the 1TB model. Meanwhile, SanDisk eschews a 120GB capacity for the Extreme Pro, going from 240GB to 1TB. The 480GB model we've tested sports 512MB of DRAM cache.

Both firms have performance-enhancing tricks in the firmware too. With Plextor, there's

the TrueSpeed feature, designed to restore drive performance when it's idle, which sounds suspiciously like TRIM, which isn't supported on every operating system. There's also TrueProtect, a fancy term that encompasses AES 256-bit encryption with some further error checking. SanDisk's nCache Pro caching also makes a comeback, with a similar system to Samsung's TurboWrite, where a small portion of the capacity is used as SLC cache.

Plextor also provides a generous five-year warranty, but SanDisk takes the warranty crown by offering ten years, in response to Samsung's offering. Another notable difference between the two drive ranges is the price. The 256GB Plextor M6 Pro is considerably more expensive than other 256GB drives, with a cost of 52p per gigabyte, almost at the level of Intel's SSD 730. There's a saving to be had by opting for the larger capacity, where the price drops to 49p per gigabyte, but this price is still well above that of many competing drives. SanDisk's Extreme Pro is slightly cheaper, but at 47p per gigabyte, it's still costly.

In terms of performance, both drive ranges sit mid-table when it comes to synthetic tests, with reasonable speeds of around 525MB/sec for sequential read, with the 512GB M6 Pro hitting a 495.8MB/sec write speed. Random read and write speeds,

along with speeds are mostly towards the middle of the chart, with the Extreme Pro hitting 39.2 MB/sec random read and the M6 Pro claiming the top spot in the 32-queue-depth random read tests

In the real-world tests, the Extreme Pro had the worst boot time of any drive on test, although the M6 Pro came top in the Microsoft Word trace test, with the rest of the results sitting around the middle. The test results aren't remarkable, and as both these ranges of SSDs are relatively pricey, without offering a huge speed gain over the other brands, they're up against fierce competition.

Conclusion

With so many SSDs offering similar synthetic and real-world performance, an SSD needs to either be an amazing performer or offer brilliant value for money to make an impact. The Plextor M6 Pro and SanDisk Extreme Pro are both good SSD ranges, but there's no single aspect to either of them that makes them stand out, meaning there are better options available in terms of both performance and value for money. **OB**

VERDICT

Both decent ranges of SSDs, but fierce competition means they struggle to stand out in terms of performance or value.



PLEXTOR M6 PRO 256GB



PLEXTOR M6 PRO 512GB



SANDISK EXTREME PRO 480GB



SanDisk Ultra II 240GB / £83 inc VAT

SUPPLIER www.amazon.co.uk

While SanDisk's Extreme Pro range (see opposite) aims for the top end of the market, its cheaper Ultra II series caters for the mid-level segment. All SSD manufacturers seem to be employing a similar strategy for their cheaper drives: shave off a few features, along with some performance via cut-down controllers that are cheaper to build, enabling them to cut a great deal off pricing.

In the case of the Ultra II, though, SanDisk has gone a little further. As with Samsung's SSD 850 Evo, it uses triple-layer (TLC) flash memory, using the company's own 128Gb 19nm NAND, allowing larger capacities to be reached with fewer chips.

And as with Crucial's BX100 range, hardware encryption has been dropped completely, with the warranty cut to just three years. The Ultra II in four capacities: 120GB, 240GB, 480GB and 960GB, with the 240GB model on test in this Labs.

Two separate controllers are employed across the Ultra II fleet, Marvell's 4-channel 88SS9190 in the 120GB and 240GB models, and Marvell's 8-channel SS889189 in the 480GB and 960GB.

SanDisk mitigates the performance and endurance issues of TLC flash memory in a similar way to other firms, with a portion of the drive's capacity reserved for use as SLC flash, which it calls nCache 2.0. Accordingly, 5GB of the Ultra II's capacity is reserved in the 120GB model, and this allocation doubles as the capacity increases: 10GB in the 240GB model, 20GB is reserved for the 480GB and 40GB in the 960GB.

One technical difference between SanDisk's system and those of other manufacturers is the way transfers are made between SLC and TLC storage with nCache 2.0. Usually, such a system reads data from the SLC storage into an SSD's DRAM cache, then writes it to the TLC portion of the drive. With nCache, this work is all done on the chip itself, without having to access the drive's DRAM, leading to vastly reduced latency times and better performance.

With a retail price of almost £83, and a formatted capacity of 224GB, the Ultra II costs 37p per gigabyte of storage, which



isn't quite as good value as Crucial's 250GB BX100 (32p) or Samsung's SSD 850 EVO (36p), but it's still reasonable.

From the synthetic benchmark results, Ultra II sits slap bang in the middle of most of the charts, with very promising sequential read results in CrystalDiskMark of 545.3MB/

sec, with write speeds down to 464MB/sec in AS SSD – a small drop but not a terrible worry. In random read and write tests, the Ultra II storms ahead of pricier drives such as Intel's 730 too, and constantly puts Crucial's BX100 to shame. However, the measured IOPS is worryingly low. The Ultra II's result of 19,647 is the lowest of all the SSDs we tested, and around half the result achieved by the Samsung 850 Evo. It's the real-world trace results that really count, though, and the Ultra II does fine here. Although its results are

Conclusion

The Ultra II fares well in real-world performance tests, and does a reasonably good job in synthetic tests too. It's a good drive and not too expensive. But ultimately it falls into a difficult spot between the more affordable Crucial BX100 and Samsung's better-performing SSD 850 Evo, and both drives offer a better balance of performance and value for money. **OB**

VERDICT

An affordable drive with good performance, but fierce competition from Samsung and Crucial puts it in a tough spot.

A portion of the drive's capacity is reserved for use as SLC flash, called nCache 2.0

sec, with write speeds down to 464MB/sec in AS SSD – a small drop but not a terrible worry. In random read and write tests, the Ultra II storms ahead of pricier drives such as Intel's 730 too, and constantly puts Crucial's

BX100 to shame. However, the measured IOPS is worryingly low. The Ultra II's result of 19,647 is the lowest of all the SSDs we tested, and around half the result achieved by the Samsung 850 Evo.

It's the real-world trace results that really count, though, and the Ultra II does fine here. Although its results are



SPEED	£/GB	OVERALL SCORE
43/50	17/20	84%
BANG/BUCK	24/30	

Intel SSD 730 240GB and 480GB

Intel SSD 730 240GB / **£138** inc VAT

SUPPLIER www.amazon.co.uk

Intel SSD 730 480GB / **£250** inc VAT

SUPPLIER: www.amazon.co.uk

In the early days of SSDs, Intel was one of the biggest players, mostly thanks to the X-25M, which offered a significant step up in quality from a lot of other solid state products at the time. Since then, the company has retreated a little and, like many other brands, often relies on third-party SandForce controllers. Intel has a strong focus on expensive enterprise-level SSDs, of course, but it still has an interest in the consumer market, and the Intel name alone still carries a lot of weight.

The SSD 730 is almost a year old now, and Intel has a replacement right around the corner, but unfortunately not soon enough for us to acquire pre-production samples for testing in this Labs.

With that caveat in mind, the 730 is still the top-end Intel consumer SSD at the moment, and it seems the company is now moving back to using its own controllers. The 730 is built using 20nm Micron 2-bit MLC NAND, with a 600MHz PC29AS21CA0 controller, which has been taken directly from the DC3700 enterprise SSD.

Power-loss protection and a parity-based redundancy system are built in, giving the 730 a fair bit of resilience. The drive's endurance is rated at 50GB a day for the 240GB model and 70GB a day for the 480GB drive, both for a reasonable five years of use.

However, the 730 shows one of the largest variances in performance between different capacities of all the drive series we tested, in synthetic tests at least. Both the 480GB and 240GB drives manage a slightly disappointing 484MB/sec in CrystalDiskMark, but AS SSD reports quicker speeds of 524MB/sec and 517MB/sec respectively.

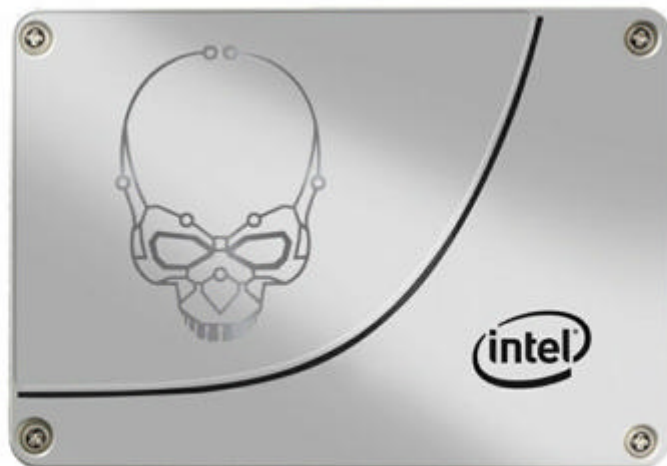
When writing, though, the 240GB model drops right near the bottom of the charts, managing just 270MB/sec in AS SSD – a disappointing showing compared with Samsung's 850 Evo 250GB, which managed 499.6MB/sec. The 480GB model fares much better, with performance hovering around 477MB/sec.

Meanwhile, when it comes to random reads and writes, the 730 is in the middle of

the chart, with respectable results, which is fine, but it equally shows that the 730 isn't the top performer.

Likewise, its IOPS performance isn't the worst we've seen, but it isn't particularly high either, especially for the 240GB drive, which only managed 32,894 IOPS.

Once again, though, our focus is on real-world performance from traces of major applications, and the 730 does fine here, with the 480GB model coming first in the Microsoft Word test, admittedly only by 0.1 seconds. It does well in the Battlefield 3 trace too, coming second only to Samsung's drives,



Crucial's 500GB BX100, which performs better in some tests. Costing 62p per gigabyte for the 240GB 730, and 56p for the 480GB drive, the prices are like those from yesteryear, ignoring the steady drop in SSD prices. Since nearly all of the other SSDs we've tested in this Labs perform almost as well, but don't cost as much, we'd choose them every time over the 730.

Conclusion

Our single wish for Intel's next-generation consumer SSDs is more realistic pricing. Crack that, and Intel will again have a product worth recommending. Otherwise, there's nothing special about the 730 and nothing to justify its higher costs. For now, we'd consider a Crucial or Samsung drive instead. **OB**

The 480GB model came first in the Microsoft Word test, but only by 0.1 seconds

with a score of 132.9 seconds for the 480GB drive and 133.2 for the 240GB model.

It's safe to conclude that the 730 offers perfectly fine real-world performance, then, but we wouldn't recommend it. It's the most expensive drive in this Labs, with the 240GB model costing almost the same amount as

VERDICT

Reasonable real-world performance, but the prices are simply too high to make these drives worth considering over the competition.

INTEL SSD 730 240GB



INTEL SSD 730 480GB



Samsung 850 Evo 250GB, 500GB and 1TB

Samsung 850 Evo 250GB / **£85** inc VAT

SUPPLIER www.amazon.co.uk

Samsung 850 Evo 500GB / **£163** inc VAT

SUPPLIER www.amazon.co.uk

Samsung 850 Evo 1TB / **£310** inc VAT

SUPPLIER www.cclonline.com



Samsung's SSD 850 Evo uses 3D V-NAND, the firm's proprietary technology for vertically arranging flash memory cells. We've explained the advantages of V-NAND in the 850 Pro review on p52, and it's clear that it adds considerably to the cost of SSD production. The 850 Evo aims for a lower price than the 850 Pro, but its prices aren't the lowest around. The Crucial BX100 and OCZ Arc 100 are both more affordable, as is the Kingston SSDNow V300.

There's 256MB of LPDDR2 cache in the 120GB model, 512MB in the 240GB and 480GB drives, and 1GB in the 1TB model. Most of the Evo drives use a dual-core MGX controller, rather than the triple-core MEX controller in the 850 Pro, although the latter is used in the 1TB drive, as its larger cache necessitates a faster controller.

The 850 Evo notably uses 40nm three-bits-per-cell (TLC) flash, as opposed to the 2-bit MLC of most SSDs, making it the first SSD to contain both TLC and 3D NAND. TLC often leads to reduced performance and endurance but, thanks to the magic of 3D V-NAND, some firmware optimisation and an SLC cache called TurboWrite, the 850 Evo drives still run fantastically well.

With TurboWrite, a small portion of the available capacity is treated as 1-bit-per-cell SLC flash, which offers higher performance when used as a cache for the main TLC flash. As long as you're writing to the SLC cache, performance will remain as high as you'd expect from any top-end MLC-based SSD, but once you've gone over that with a write command, the speed will drop to TLC-level

performance until the 850 Evo has time to write the data back to the TLC portion of the drive. There's 3GB of SLC cache in the 250GB model, 6GB in the 500GB and 12GB in the 1TB. In everyday use, it's unlikely you'll perform many writes that go over this limit, though, and we didn't encounter it in our tests.

Hardware encryption with AES 256-bit and TGC Opal standards are supported, as is the low-power DEVSLP mode. As with the 850 Pro, the 850 Evo also supports Samsung's Rapid RAM cache, as part of the Magician software.

Synthetic performance results are excellent, with the 850 Evo breaking the 530MB/sec barrier in sequential reads, and jostling for position with the 850 Pro for sequential writes.

The 250GB and 500GB drives top the charts for higher queue-depth read and write performance as well, with the 1TB lagging behind slightly.

In real-world tests, the 850 Evo once again fares well. The 1TB model achieved the best Battlefield 3 trace result, the second best PCMark 7 result and was close to the top in the Microsoft Word and Photoshop Heavy tests too. The 250GB and 500GB capacities weren't quite as good, but since the



differences between these results are so small, there's no reason for complaint.

Conclusion

The 850 Evo brings the benefit of 3D V-NAND to a wider audience due to better affordability than the 850 Pro. It performs well in synthetic tests, brilliantly in real-world tests and is competitively priced. Its SLC cache is large enough not to get in the way of performance, and the 850 Evo supports encryption and low-power consumption features, along with the extras offered by Samsung's Magician software, such as Rapid mode. This mix of affordability, performance and features makes for a winning combination. **OB**

VERDICT

A winning combination of reasonable pricing, plenty of features and great performance.

SAMSUNG 850 EVO 250GB



SPEED
47/50
£/GB
17/20
BANG/BUCK
26/30

OVERALL SCORE
90%

SAMSUNG 850 EVO 500GB



SPEED
48/50
£/GB
18/20
BANG/BUCK
27/30

OVERALL SCORE
93%

SAMSUNG 850 EVO 1TB



SPEED
46/50
£/GB
18/20
BANG/BUCK
27/30

OVERALL SCORE
91%

Samsung SSD 850 Pro 256GB, 512GB and 1TB

Samsung SSD 850 Pro 256GB / **£125** inc VAT

SUPPLIER www.amazon.co.uk

Samsung SSD 850 Pro 512GB / **£239** inc VAT

SUPPLIER www.cclonline.com

Samsung SSD 850 Pro 1TB / **£405** inc VAT

SUPPLIER www.amazon.co.uk



In a few significant ways, the 850 Pro is the most advanced 2.5in SSD on the market. So far, Samsung remains the only company to sell products based on 3D NAND, where layers of cells are stacked on top of each other, as well as horizontally. Samsung's own implementation of this idea is called 3D V-NAND.

Improved chip density due to shrinking transistor and cell sizes alone has hit a brick wall. As cells get smaller, their reliable storage of data becomes increasingly difficult. Smaller cells mean less space between them, meaning a greater chance of interference when a neighbouring cell is passed voltage for a write or erase command.

Smaller floating gates also means greater insulator wear, reducing drive endurance. Instead of increasing density via traditional means, when cells are layered on top of one another with V-NAND, larger cells can be used, which is why Samsung can use 40nm MLC flash in the SSD 850 Pro, mitigating the aforementioned issues.

V-NAND has real-world benefits too, from improved performance to impressive endurance figures. All 850 Pro drives are rated for 150TB of writes, considerably more than rivals. Samsung is backing this up with a ten-year warranty too. It helps that Samsung is also the only SSD manufacturer to control every aspect of its products, including the NAND flash chips, the controller design, the firmware and the DRAM cache. The triple-core MEX controller in the 850 Pro runs at 400MHz, with 256MB of LPDDR2 cache in

the 128GB model, 512MB in the 256GB and 512GB models, and 1GB of cache in the 1TB 850 Pro.

In the CrystalDiskMark sequential read test, all three 850 Pro drives claim the top spot with the same speed of 551.4MB/sec, while in the write tests, it jostles for first place Samsung's 850 Evo drives. Although it doesn't come top in every random read and write test, the 850 Pro again comes close, and once again claims a close second place to the 850 Evo in 32 and 64-queue-depth tests. Meanwhile, in Iometer all three 850 Pro drives managed the best IOPS result by some margin, being 1,400 points ahead of the nearest rival.

There are two snags that prevent the 850 Pro from achieving total domination. Firstly, the sheer scale of the engineering effort that went into the 850 Pro is reflected in the prices: 52p per gigabyte for the 256GB model, 50p for the 512GB and a more reasonable 42p for the 1TB. You're paying considerably more than with the majority of other brands.

Also, the outstanding synthetic performance results don't translate into similarly impressive real-world performance gains. Although it doesn't come top, the 850 Pro does well in the PCMark 8 Photoshop

Heavy and Microsoft Word traces, but any advantage is measured in a fraction of a second, too small to make any noticeable difference in use. Any difference in boot times is similarly tiny, with the 1TB 850 Pro being 1.8 seconds slower than the 512GB model.

Conclusion

The 850 Pro's advantage in synthetic tests doesn't result in significantly better real-world performance, and most people would struggle to notice the speed difference between the 850 Pro and a more affordable SSD. However, the 850 Pro's superb IOPS performance, ten-year warranty and solid endurance figures make it a brilliantly fast choice for workstation users. **OB**

VERDICT

The 850 Pro's outstanding performance and endurance is wasted on a consumer desktop PC, but it's ideal for workstation users.

SAMSUNG SSD 850 PRO 256GB

SPEED
47/50
BANG/BUCK
20/30

£/GB
11/20

OVERALL SCORE
78%

SAMSUNG SSD 850 PRO 512GB

SPEED
48/50
BANG/BUCK
21/30

£/GB
12/20

OVERALL SCORE
81%

SAMSUNG SSD 850 PRO 1TB

SPEED
47/50
BANG/BUCK
23/30

£/GB
15/20

OVERALL SCORE
85%

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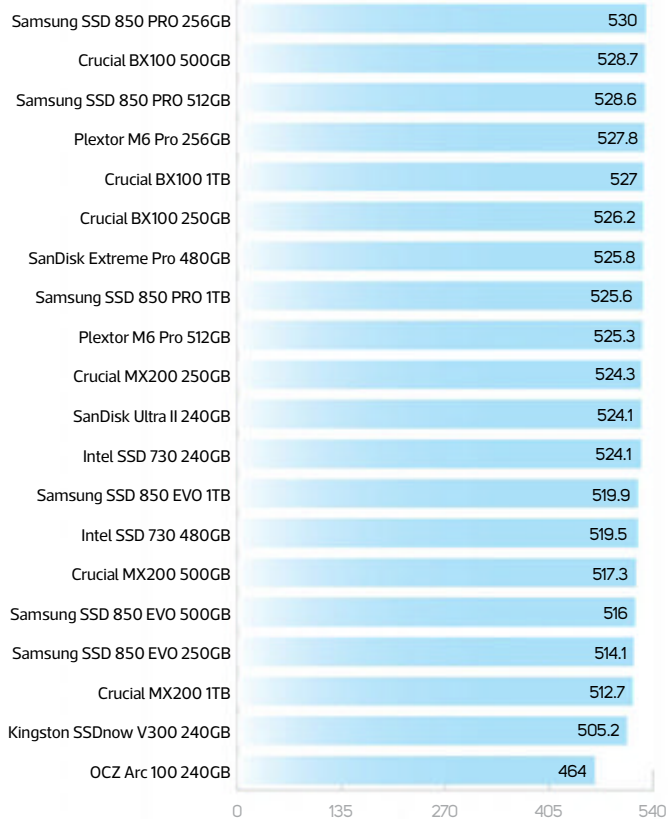


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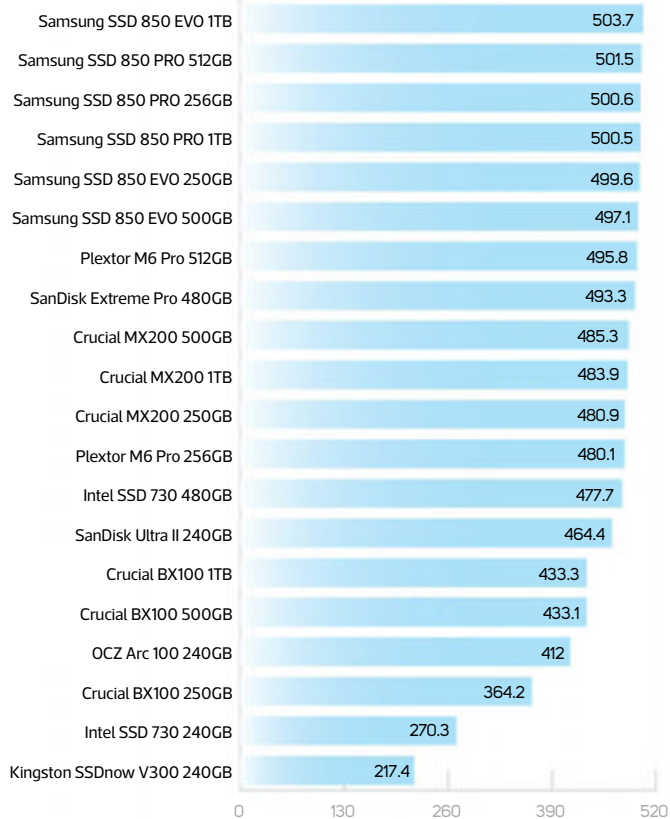
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AS SSD

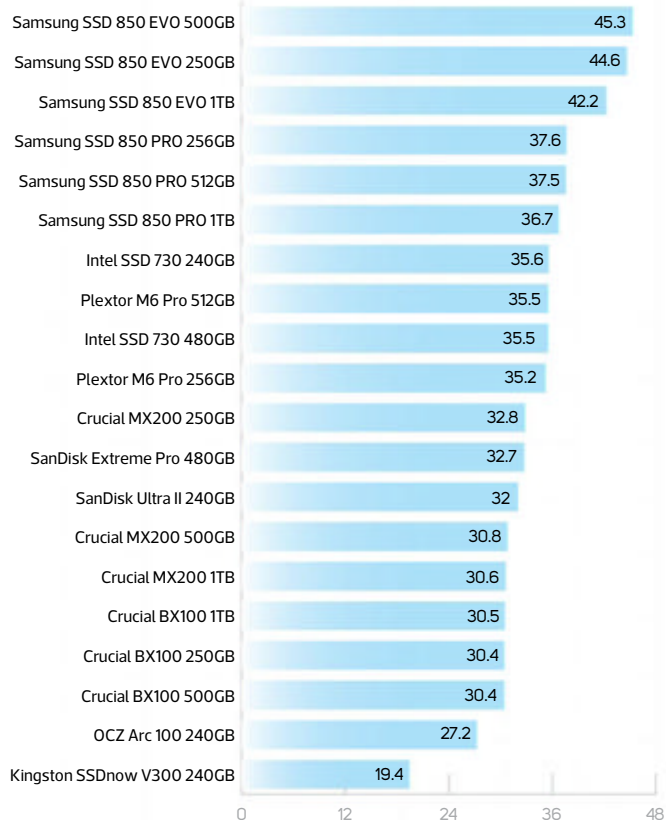
Sequential read (MB/sec)


AS SSD

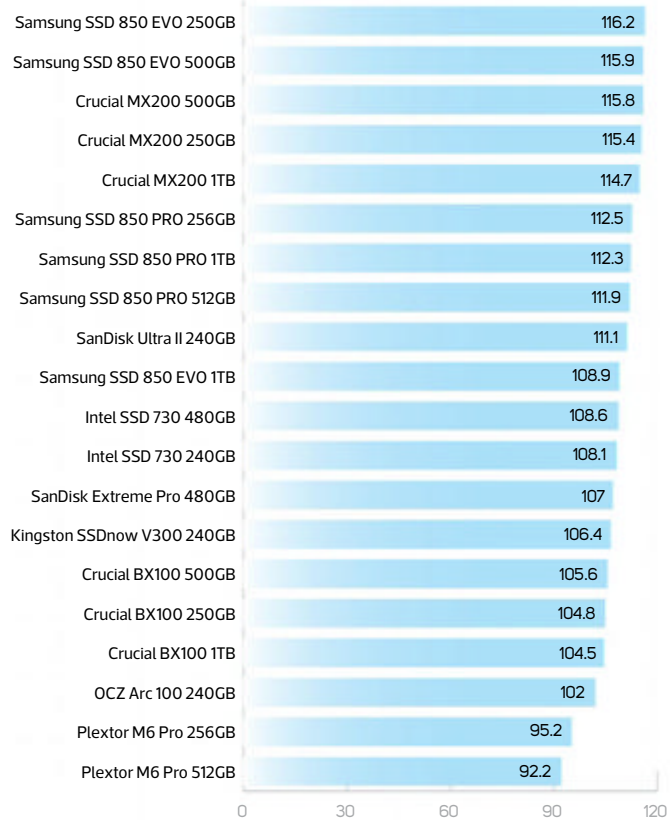
Sequential write (MB/sec)


AS SSD

4KB random read (MB/sec)

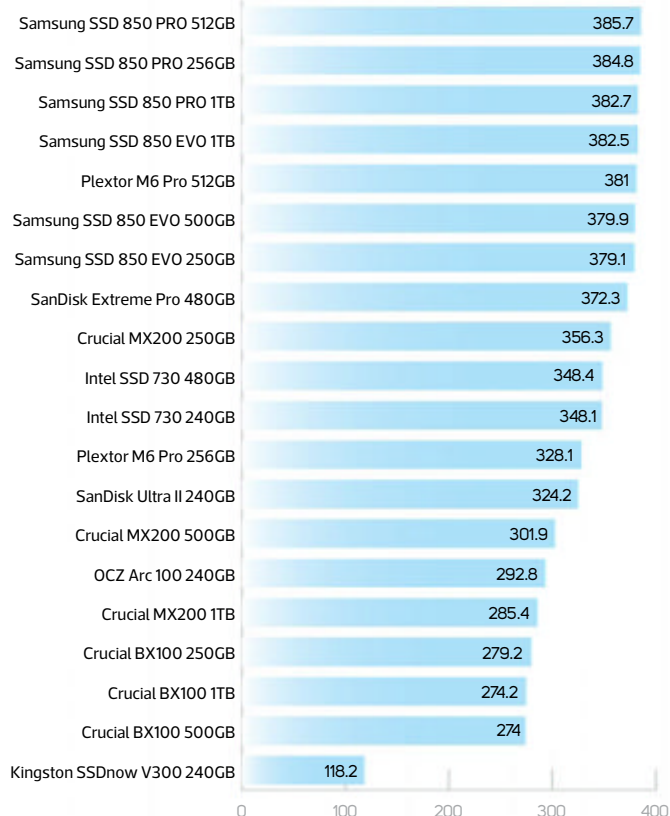

AS SSD

4KB random write (MB/sec)

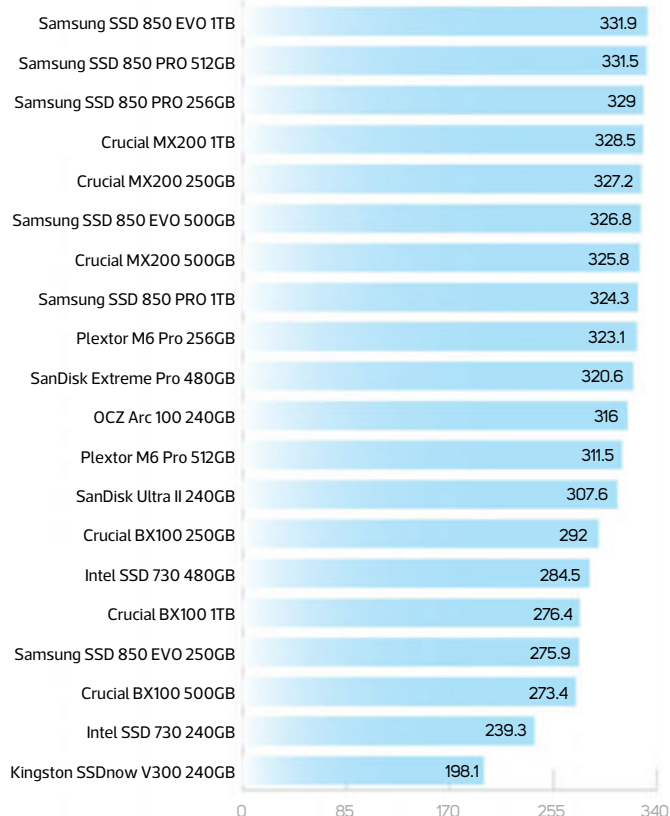


AS SSD

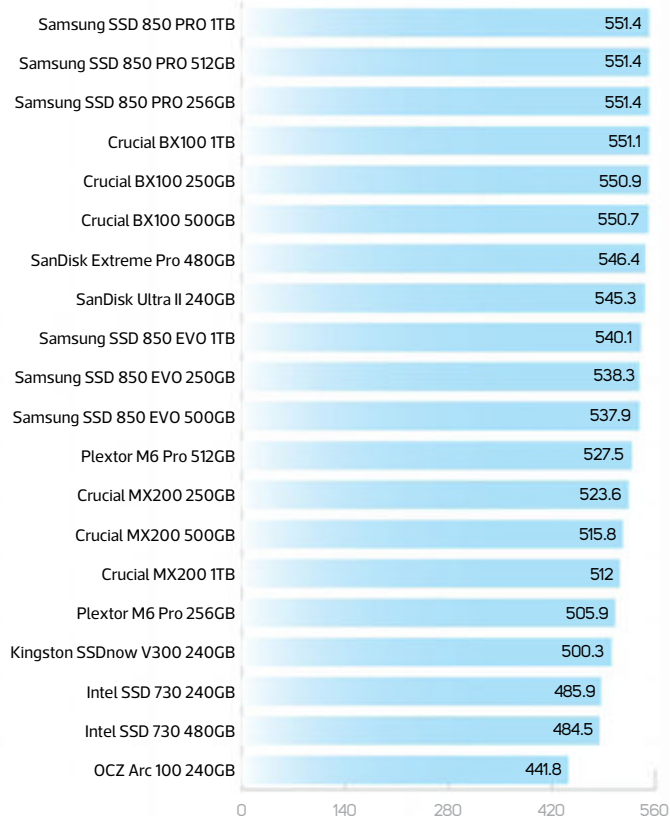
64-queue-depth 4KB random read (MB/sec)

**AS SSD**

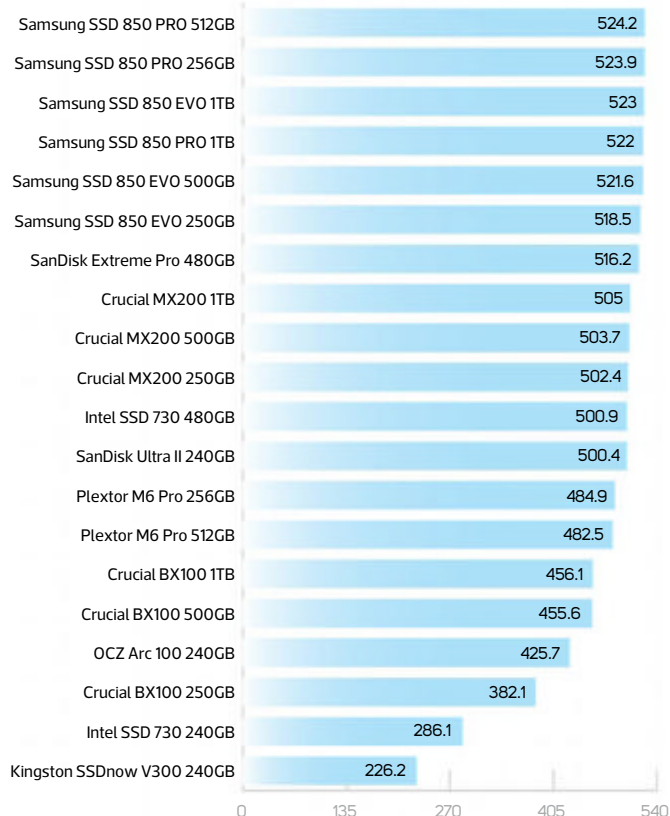
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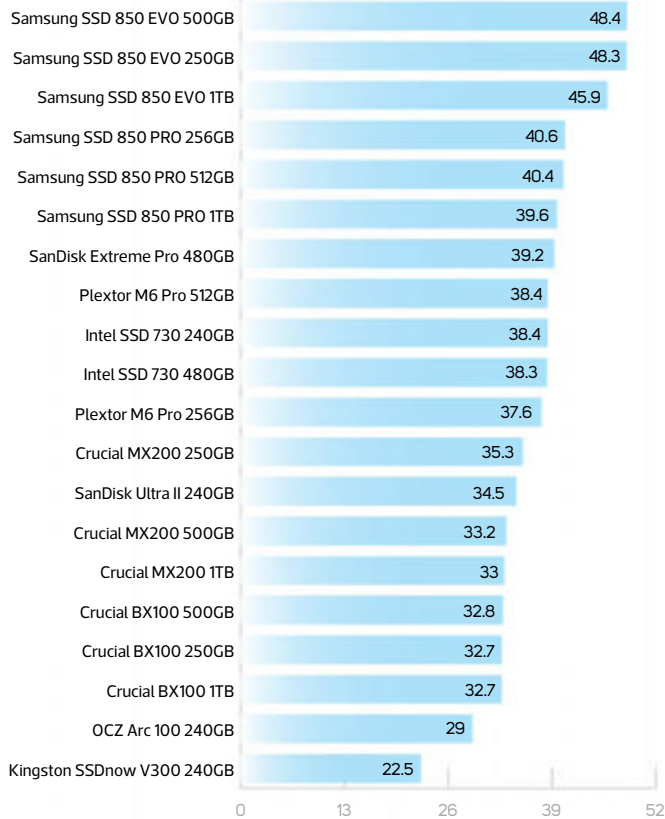
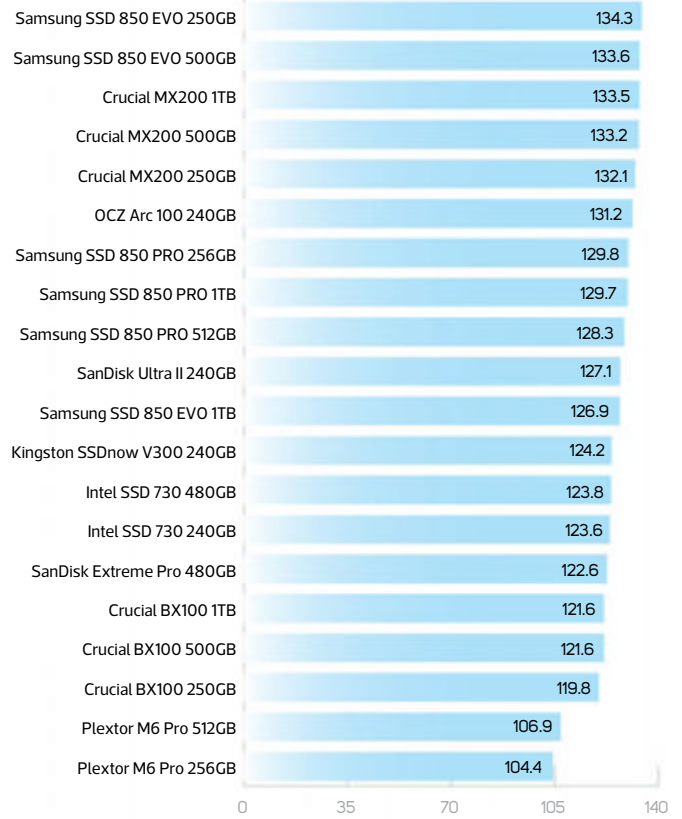
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Sequential read (MB/sec)

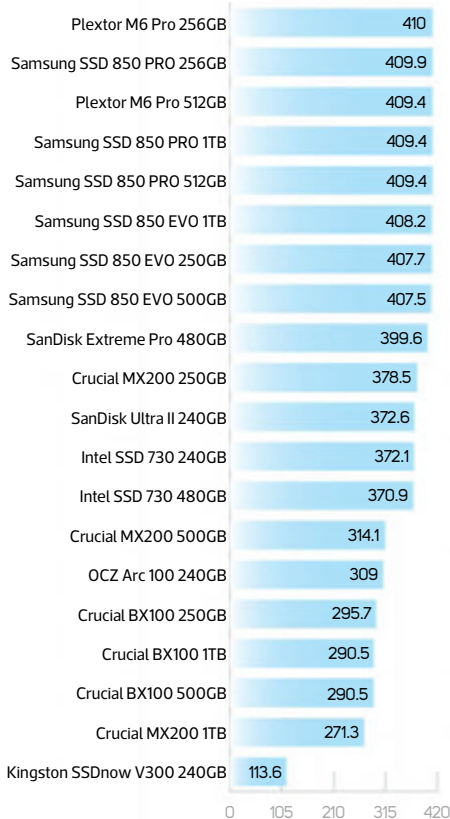
**CRYSTALDISKMARK**

Sequential write (MB/sec)

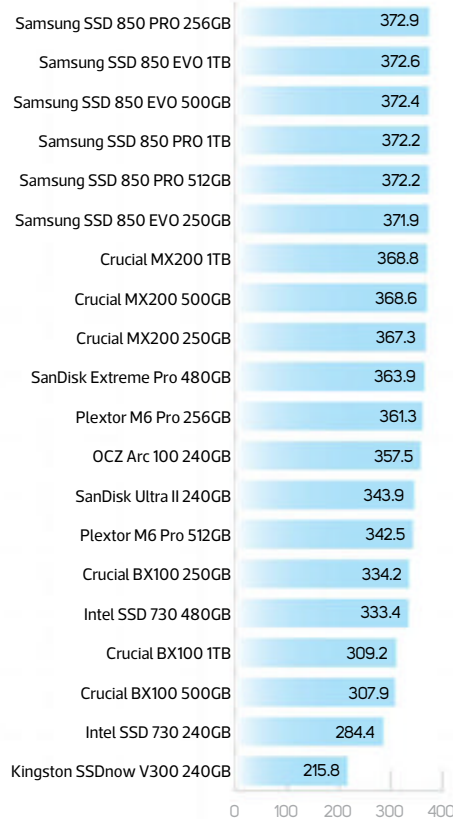


CRYSTALDISKMARK
4KB random read (MB/sec)

CRYSTALDISKMARK
4KB random write (MB/sec)

CRYSTALDISKMARK

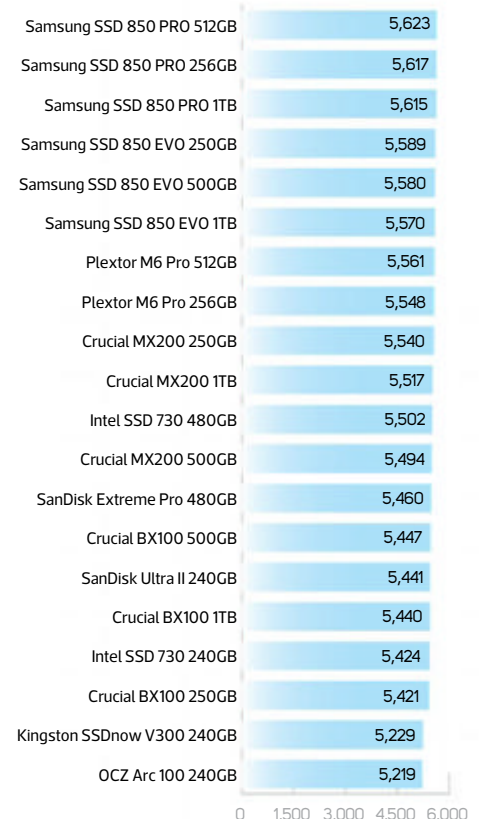
32-queue-depth 4KB random read (MB/sec)


CRYSTALDISKMARK

32-queue-depth 4KB random write (MB/sec)

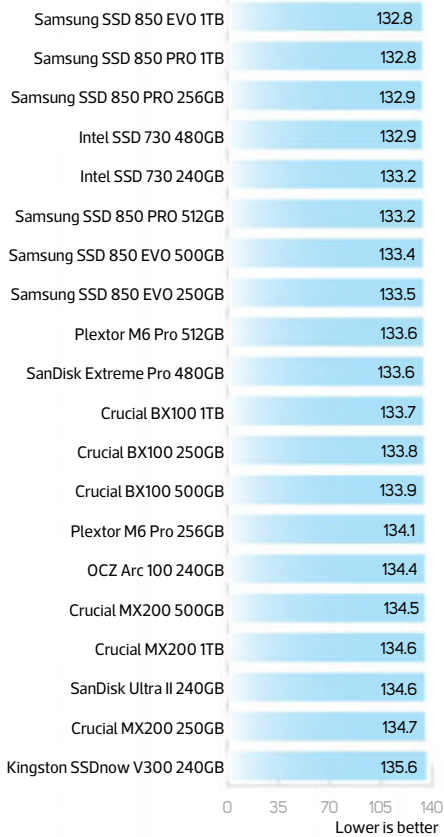

PCMARK 7

Secondary storage score

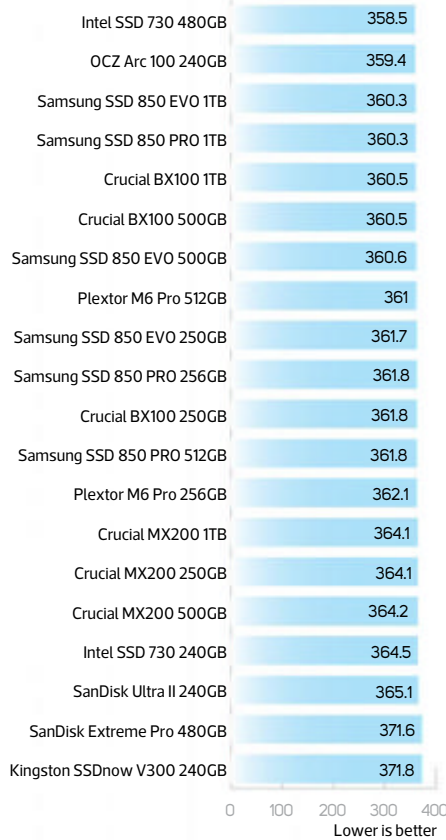


PCMARK 8

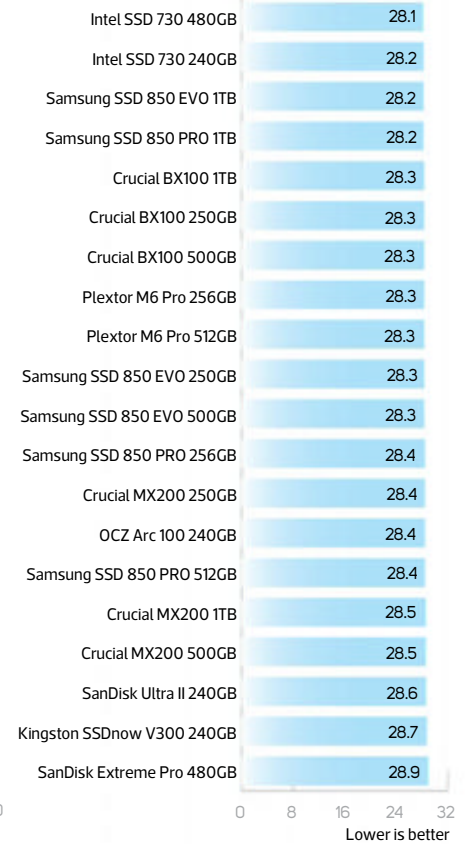
Battlefield 3 trace (seconds)

**PCMARK 8**

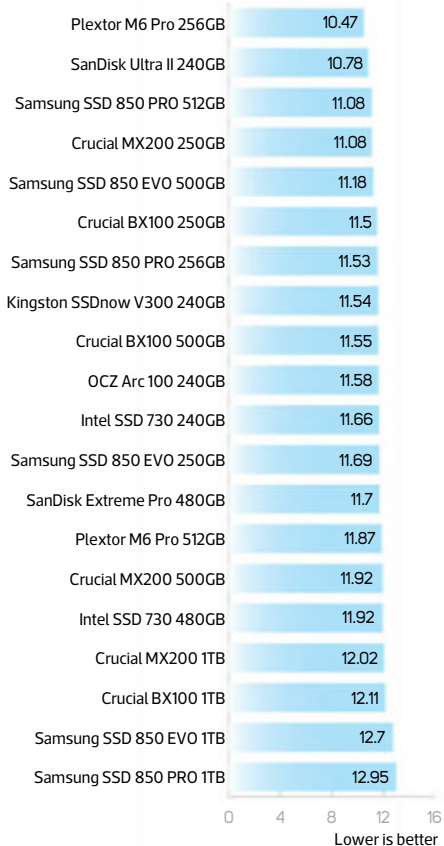
Photoshop heavy trace (seconds)

**PCMARK 8**

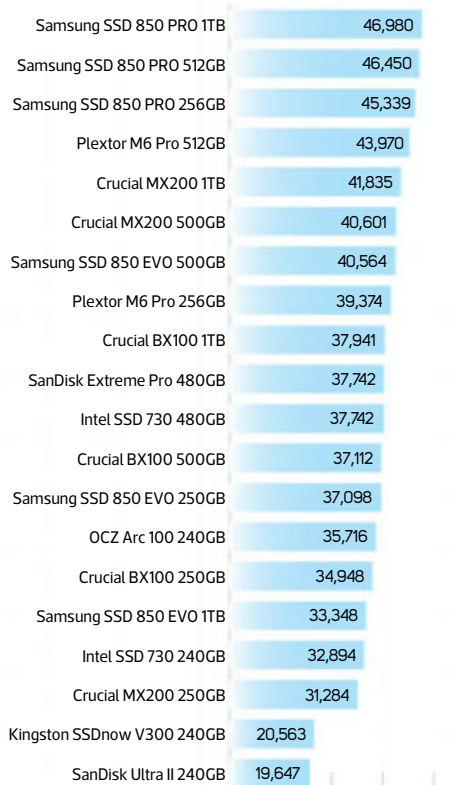
Microsoft Word trace (seconds)

**BOOTRACER**

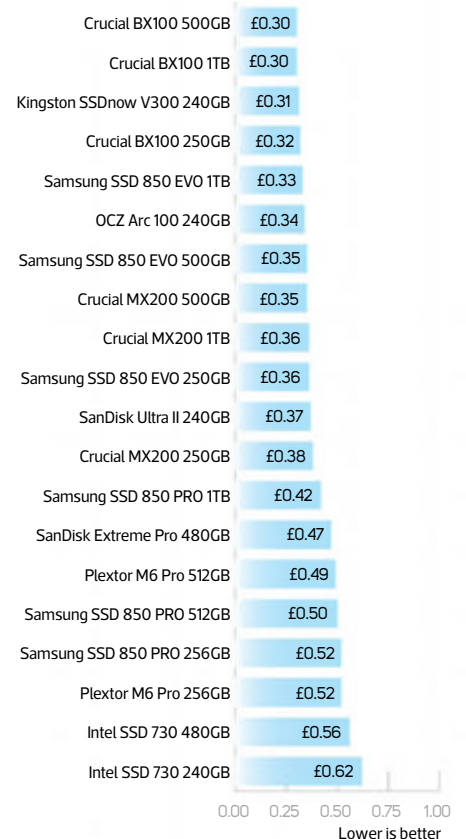
Windows 7 64-bit boot time (seconds)

**IOMETER**

Mixed workloads average (IOPS)

**COST/GB**

Retail price over formatted capacity (£/GB)



PC system reviews

GAMING PC

Overclockers Infin8 Nebula / £3,116 inc VAT

SUPPLIER www.overclockers.co.uk

The latest system from Overclockers is one of the most powerful we've seen, and its cooling system is one of the slickest and most extensive water-cooling rigs we've seen for a long time.

The loop is dominated by the cylindrical Bitspower Z-Multi 150mm reservoir attached to the hard disk cage. The top of the chassis houses an XSPC RX360 radiator, and a 240mm XSPC radiator sits on the exhaust mount. The Mayhems X1 coolant delves from the reservoir to the EK Supremacy Evo block on the CPU, and then heads downwards to a pair of EK FX980 blocks across the Nebula's pair of GTX 980 GPUs. The coolant then heads to the 240mm radiator, then up to the 360mm unit, before starting its journey again – and it's all powered by an XSPC D5 PWM pump.

Photography: www.overclockers.co.uk

/SPECIFICATIONS

CPU 4GHz Intel Core i7-4790K overclocked to 4.6GHz

Motherboard Asus Maximus VII Gene

Memory 16GB Kingston HyperX Genesis 2,400MHz DDR3

Graphics 2 x Asus GeForce GTX 980 4GB

Sound On-board Asus SupremeFX

Storage Samsung 850 EVO 250GB; 3TB Seagate Barracuda hard disk

Case Phanteks Enthoo Mini XL

Cooling CPU: EK Supremacy Evo waterblock; GPU: 2 x EK FC980 GTX waterblocks, EK FC Terminal Dual Parallel GPU interconnection; XSPC D5 PWM pump, XSPC EX240 radiator, XSPC EX360 radiator, Bitspower Z-multi 150mm reservoir, 5 x Noiseblocker NB-eLoop fans, Mayhems X1 coolant

PSU SuperFlower Leadex Gold 850W

Ports Front: 2 x USB 3, 2 x audio; Rear: 4 x USB 3, 4 x USB 2, 1 x Gigabit Ethernet, 1 x PS/2, 1 x optical S/PDIF, 3 x audio

Operating system Windows 8.164-bit

Warranty Two years collect and return parts and labour, third year labour only

It's an effective system, and Overclockers has worked to make it aesthetically pleasing too. A light-strip starts at the bottom of the case, beneath the graphics cards, and carries on to the back of the chassis, and a button on the front panel flips between ten different colours. The position of the lighting makes it look as though the illumination is inside the reservoir and waterblocks, and it provides a striking view through the Nebula's window.

The large Phanteks Enthoo Mini XL (see p24) case is also striking. It's hewn from steel and sand-blasted aluminium, and its dark front panel is indented with a meshed area next to a raised ridge that houses the buttons and front-facing I/O. It's heavy too, and build quality is reassuring.

The SSD is attached to one of two 2.5in drive mounts on the rear of the motherboard tray, and the PSU sits sideways on rubber pads in the top corner of the chassis, behind the two radiators. Dust is kept at bay thanks to a variety of magnetic and push-to-release filters, and it's impeccably tidy, with cables hidden away behind the motherboard tray and water-cooling hardware. We only have a minor quibble, which is that the sheer volume of hardware inside the case makes it a little cramped – working inside the Nebula requires delicacy and precision.

The busy interior isn't a major problem, though, because there isn't a huge amount of room to grow. Two memory slots and some



SATA connectors are free, but the graphics cards block the M.2 connector and the 1x PCI-E slot. Various storage bays lie vacant around the case, but the intricate build and sheer power available mean it's unlikely many users will add extra hardware.

Thanks to the cooling system, the 4GHz Intel Core i7-4790K has been overclocked from 4GHz to 4.6GHz, and it's paired with 16GB of 2,400MHz DDR3 memory. This CPU provides more than enough power for most work and play, although anyone wanting to run highly demanding multi-threaded applications would be better off with an LGA2011 machine.

Meanwhile, the impressive Asus Maximus VII Gene has power and reset buttons at the bottom, a mini PCI-E slot at the very top and SupremeFX audio. It looks good too, with lighting on its heatsinks, and the I/O is well stocked, with quartets of USB 3 and USB 2 ports, a clear-CMOS button, an optical S/PDIF output and a PS/2 connector. The two GPUs mean the pair of PCI-E slots run at 8x speed, but that's still enough bandwidth to avoid a performance bottleneck.

Windows 8.164-bit is installed onto a 250GB Samsung 850 Evo SSD (see p51), and there's a 3TB Seagate hard disk. The latter is a huge amount of storage for games, although a larger SSD would be preferred for this machine's price. Speaking of which, it's possible to save money on this PC by dropping down to a single GTX 980. That move restricts the Nebula to 2,560 x 1,440 gaming, but it does save you £585.

The Nebula also includes the standard Overclockers three years warranty, which includes two years of collect and return parts coverage, and one year of labour coverage.

Performance

The pair of GTX 980 cards makes for a 4K-capable system. In our Ultra-quality Battlefield 4 benchmark at 3,840 x 2,160 the Nebula hit a smooth minimum of 37fps, and the Nebula went beyond the crucial 30fps figure in Crysis 3 too. In short, this is one of the fastest gaming machines we've ever seen.

The overclocked CPU proved rapid too. Its overall benchmark result of 132,078 is great, and only a handful of systems have proved significantly faster, and they all use LGA2011 hardware. This is ample power unless you regularly deal with heavily multi-threaded workloads.

The cooling system worked flawlessly too. The overclocked processor's maximum delta T of 58°C is far below the chip's thermal limits, and the graphics cards were even cooler – they topped out with delta Ts of just 30°C. It's consistently quiet too, with only a low whirr to be heard, even during tough game benchmarks.

Conclusion

The Nebula deeply impresses in every respect. Its water-cooling system looks superb and works admirably, and it's used to chill a trio of powerful components; the processor has undeniable speed, and the pair of graphics cards enable



1
The pair of water-cooled GTX 980 cards make for a 4K-capable system

2
The gorgeous water-cooling loop incorporates two radiators, a Bitspower Z-Multi reservoir and Mayhems X1 coolant

3
The Core i7-4790K CPU is overclocked to 4.6GHz, resulting in some great benchmarks

smooth 4K gaming. There's no denying the price, though, especially when a fair amount of cash has gone on aesthetics. However, if you have the money, and you want a powerful, well-built, cool and great-looking machine, this 4K gaming rig is superb.

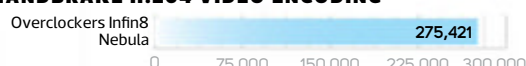
MIKE JENNINGS

CUSTOM PC REALBENCH 2014

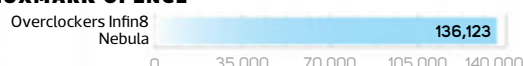
GIMP IMAGE EDITING



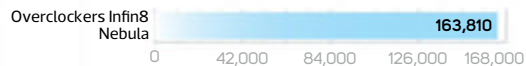
HANDBRAKE H.264 VIDEO ENCODING



LUXMARK OPENCIL



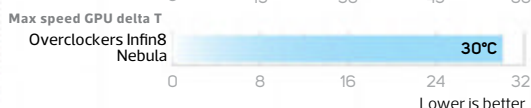
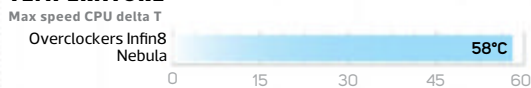
HEAVY MULTI-TASKING



SYSTEM SCORE



TEMPERATURE



BATTLEFIELD 4

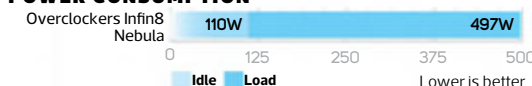


CRYSIS 3

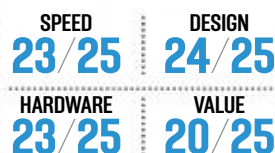


Stock speed min Stock speed avg

POWER CONSUMPTION



Lower is better



VERDICT

Impressive in almost every department. This overclocked rig might be pricey, but it's fast and beautiful.

GAMING PC

Chillblast Fusion Falcon / £1,575 inc VAT

SUPPLIER www.chillblast.com

Chillblast's latest system might be named after a bird, but its chassis is heavy and sturdy enough to keep it firmly rooted to your floor or desk. The Phanteks Enthoo Evolv case is strong and sturdy, but it's also just 450mm tall and 230mm wide – far smaller than full-sized towers, making the Fusion Falcon a tempting micro-ATX alternative to monster desktop machines without cutting performance.

The star component is a GeForce GTX 980 graphics card. Its 1,126MHz core is overclocked to a beefier 1,178MHz, and it tops out at 1,279MHz – a little higher than the stock GPU.

It's partnered with the gaming CPU of the moment – Intel's 4GHz Core i7-4790K, which Chillblast has boosted to 4.4GHz. That isn't the highest overclock we've seen, but it should be enough to help the Fusion Falcon ease through most applications.

There's 16GB of DDR3 RAM clocked at a middling 1,600MHz, and a familiar SSD and hard disk combination: a 500GB Samsung 850 Evo solid state drive (see p51) and a 2TB Seagate hard drive.

Meanwhile, the Asus Z97M-Plus is a micro-ATX board with a decent feature set. The middle of the black PCB has a spare M.2 socket, and two spare DDR3 memory slots can be used to double the amount of RAM. There are a few SATA ports free too, although you'll have to move the graphics card to access them, and the ports at the bottom of the board are fiddly to reach.

The backplate has four USB 3 ports, two USB 2 ports and a PS/2 port alongside six audio jacks, but there's no clear-CMOS button or S/PDIF output. The front I/O panel offers up two USB 3 ports and the usual audio jacks, although they all sit towards the bottom of one side panel, which could be awkward to reach, depending on the position of your PC.

Perhaps the biggest compromise with the motherboard is the lack of dual-graphics ability: this board doesn't support Nvidia SLI, and its second PCI-E slot only runs at 4x speed. There are no on-board buttons or overclocking features either.

There's also not much room inside the Phanteks case. The SSD and hard disk are relegated to a small cage beneath the PSU shroud, and there are only two bays – elsewhere, storage is limited to a single 3.5in or two 2.5in drives on the main bracket, and two more SSDs on the rear of the motherboard tray. There's no optical drive either, and the modular bay can't be used to add one, as the CPU cooler blocks its panel. That said, with changing storage requirements and falling prices, that's enough room for most people.



In other departments, the Phanteks chassis is impressive. Its side panels swing open on slick hinges, and its front and top panels pop off easily.

A plastic panel with a dust filter is installed behind the main metal façade and protects the 200mm fan, while the PSU's cables are hidden behind a thick metal shroud. The latter makes the system look tidy, and Chillblast's attention to detail is just as tidy around the back, with cables running in neat, straight lines.

Finally, the Fusion Falcon also comes with Chillblast's five-year warranty, which includes two years of collect and return coverage for parts and labour, and another three years of labour coverage after that.

Performance

Running Battlefield 4 at Ultra quality at 2,560 x 1,440, the Falcon never dropped below a solid 49fps. Crysis 3 is our toughest game, but the Chillblast was up to the task at this resolution with a very respectable minimum of 36fps.

Not surprisingly, the single-GPU Fusion Falcon was less convincing when playing games at 4K though. In Battlefield 4, its minimum frame rate dropped to 22fps, and it went all the way down to 17fps in Crysis 3.

In short, this machine is fantastic for gaming at 2,560 x 1,440, but you'll need a PC with either two GPUs or a GTX Titan X (see p18) for 4K gaming.

Meanwhile, the overclocked processor helped the Chillblast Fusion Falcon to an overall system score of 119,374 in our RealBench 2014 test. That's a rapid, and enough to handle high-end work and avoid game bottlenecks.

None of the components proved too hot for the Chillblast with its Corsair H80i cooler and 200mm intake fan either. The processor's delta T of 55°C is fine, and the highly efficient Maxwell GPU architecture meant that the GPU

Photography:
www.chillblast.com

/SPECIFICATIONS

CPU 4GHz Intel Core i7-4790K
overclocked to 4.4GHz

Motherboard Asus Z97M-Plus

Memory 16GB Crucial
CT102464BA160B 1,600MHz
DDR3

Graphics Nvidia GeForce GTX
980 4GB

Sound On-board

Storage Samsung 850 Evo
500GB; 2TB Seagate hard disk

Case Phanteks Enthoo Evolv

Cooling CPU: Corsair Hydro H80i,
2 x 120mm fans; Front: 1 x
200mm fan; PSU: Corsair RM 750

Ports Front: 2 x USB 3, 2 x audio;
Rear: 4 x USB 3, 2 x USB 2, 1 x
PS/2, Gigabit Ethernet, 6 x audio

Operating system Windows
8.1 64-bit

Warranty Five years – two years
parts and labour collect and
return, three years labour only

1

The two-fan Corsair H80i cooler keeps the overclocked CPU in check

2

The GeForce GTX 980 graphics card is great for gaming at 2,560 x 1,440

3

The power supply cables are hidden behind a thick metal shroud

delta T was just 49°C as well. The Fusion Falcon barely makes a noise when idling either, and it wasn't much louder when tasked with tough games, while drawing a modest 335W from the mains when stress-tested. Considering the power available, this is all quite an achievement.

Conclusion

The GTX 980 has ample pace for gaming at every resolution beneath 4K, the processor is quick and the rest of the specification is reasonable too. It's well-built, looks good and keeps cool. The micro-ATX form factor doesn't compromise on performance, but this particular setup does result in a few compromises.

There isn't a huge amount of upgrade room, for example, especially for multi-GPU, and full-sized rigs have more room for extra storage. If the lack of upgrade room isn't a major concern, though, the Chillblast Falcon Fusion is a sturdy, smart alternative to full-sized desktops, offering loads of power in a surprisingly quiet and small chassis.

MIKE JENNINGS

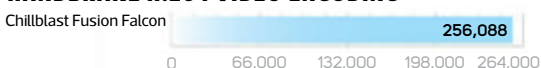


CUSTOM PC REALBENCH 2014

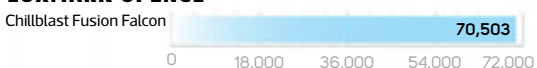
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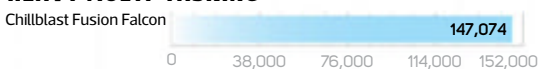
HANDBRAKE H.264 VIDEO ENCODING



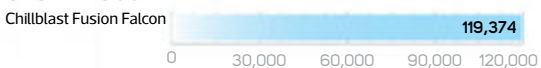
LUXMARK OPENCL



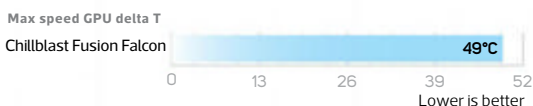
HEAVY MULTI-TASKING



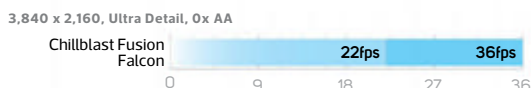
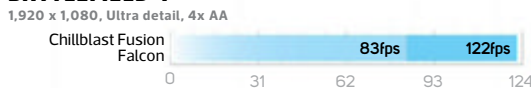
SYSTEM SCORE



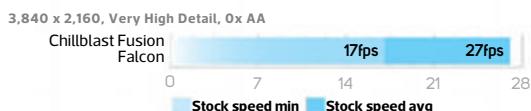
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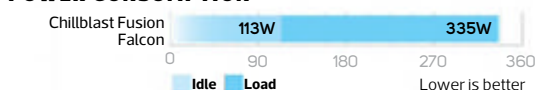
BATTLEFIELD 4



CRYSIS 3



POWER CONSUMPTION



SPEED
21/25

DESIGN
23/25

HARDWARE
22/25

VALUE
22/25

OVERALL SCORE

88%

VERDICT

Fast, well made and quiet. The Fusion Falcon is a great machine for gaming at 2,560 x 1,440, although its room for expansion is a little limited.

Elite

Our choice of the best hardware available

Build a budget PC

Core components

The parts you'll need to build either PC. This kit list gives you a solid PSU, a decent quality case and the OEM version of Windows 7 Home Premium.



	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
1	NZXT S340	www.overclockers.co.uk	Issue 137, p54	£60
2	Corsair CS550M	www.scan.co.uk	Issue 135, p46	£66
3	500GB Seagate Barracuda ST500DM002	www.scan.co.uk	Issue 104, p72	£36
4	Microsoft Windows 7 Home Premium 64-bit OEM	www.ebuyer.com	Issue 75, p46	£68

All-purpose PC

The parts you'll need to add to the core components to build a general-purpose PC. This machine will handle general computing tasks with no trouble, and will also cope with basic gaming, although you'll have to lower the detail settings. It features high-speed memory to boost the performance of the AMD APU's graphics system.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Gigabyte GA-F2A88XM-D3H	www.cclonline.com	Issue 126, p22	£53
	AMD A10-7850K	www.scan.co.uk	Issue 127, p17	£115
	8GB Corsair Vengeance Pro Series 2,400MHz DDR3	www.scan.co.uk	Issue 132, p22	£70
	SilverStone Argon AR01	www.scan.co.uk	Issue 132, p57	£26
TOTAL				£494

Gaming PC

The parts you'll need to build a budget machine capable of playing the latest games at maximum settings on a 1080p monitor. The machine has a discrete graphics card, a highly overclockable dual-core CPU and high-speed memory. Meanwhile, the Z97 motherboard gives you headroom to upgrade to a faster CPU later.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	ASRock Z97 Pro3	www.scan.co.uk	Issue 130, p50	£80
	Intel Pentium G3258	www.scan.co.uk	Issue 132, p17	£54
	AMD Radeon R9 280 3GB	www.ebuyer.com	Issue 140, p42	£140
	Corsair Vengeance Pro Series 2,400MHz DDR3	www.scan.co.uk	Issue 132, p22	£70
	SilverStone Argon AR01	www.scan.co.uk	Issue 132, p57	£26
TOTAL				£600

Recommended extra

A solid state drive will make a huge difference to the responsiveness of Windows, as well as boot-up times. We strongly recommend adding one to any build.











	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Crucial BX100 250GB UPDATED	www.ebuyer.com	Issue 141, p43	£74



Build a mid-range PC

Work PC

The parts you'll need to build a solid quad-core PC with plenty of upgrade potential. This kit list gives you an all-in-one liquid cooler and a K-series Core i5 CPU, meaning you can overclock it and get some serious processing power. We've managed to get the Core i5-4690K Haswell CPU up to 4.8GHz, so it has some serious performance potential. Also included is a solid Corsair PSU, a 500GB SSD and 8GB of high-speed memory. The core configuration assumes you won't be doing any serious gaming, however, and it relies on Intel's integrated graphics.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	NZXT Phantom 530	www.overclockers.co.uk	Issue 127, p44	£98
	Gigabyte Z97X-SLI	www.overclockers.co.uk	Issue 130, p54	£90
	Intel Core i5-4690K	www.overclockers.co.uk	Issue 132, p18	£185
	Corsair Vengeance Pro Series 2,400MHz DDR3	www.scan.co.uk	Issue 132, p22	£70
	NZXT Kraken X41	www.overclockers.co.uk	Issue 138, p57	£70
	Corsair CS550M	www.scan.co.uk	Issue 135, p46	£66
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£59
	Lite-On IHAS124-14	www.dabs.com	Issue 99, p108	£10
	Crucial BX100 500GB UPDATED	www.dabs.com	Issue 141, p43	£140
	Microsoft Windows 7 Home Premium 64-bit OEM	www.ebuyer.com	Issue 75, p46	£68
			TOTAL	£856

Gaming PC










The graphics card you'll need to play current games at their maximum settings at 1080p and 2,560 x 1,440.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	1,920 x 1,080 AMD Radeon R9 280 3GB	www.ebuyer.com	Issue 140, p42	£140
	2,560 x 1,440 AMD Radeon R9 290 4GB	www.ebuyer.com	Issue 140, p48	£218

Build a performance PC

Work PC

The parts you'll need to build a high-quality, fast PC that's ideal for multi-threaded workloads. This kit list features a high-quality, beautifully built case, and has a Core i7-4790K CPU. This processor's support for Hyper-Threading effectively splits the resources of the CPU's four physical cores into a further four virtual cores, meaning it can effectively handle eight threads at once. There's also a solid 850W PSU, giving you plenty of headroom for overclocking and adding multiple graphics cards, and an all-in-one liquid cooler.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	NZXT H440 Special Edition	www.overclockers.co.uk	Issue 140, p24	£125
	Asus Maximus VII Ranger	www.scan.co.uk	Issue 131, p20	£136
	Intel Core i7-4790K	www.scan.co.uk	Issue 132, p19	£273
	Corsair Vengeance Pro Series 2,400MHz DDR3	www.scan.co.uk	Issue 132, p22	£70
	NZXT Kraken X41	www.overclockers.co.uk	Issue 138, p57	£70
	SilverStone Strider Gold 850W	www.scan.co.uk	Issue 135, p56	£104
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£59
	Samsung 850 Evo 500GB UPDATED	www.amazon.co.uk	Issue 141, p51	£163
	Microsoft Windows 7 Home Premium 64-bit OEM	www.ebuyer.com	Issue 75, p46	£68
			TOTAL	£1,068

Gaming PC

The graphics card you'll need to play current games at their maximum settings at 2,560 x 1,440 and beyond.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	2,560 x 1,440 AMD Radeon R9 290 4GB	www.ebuyer.com	Issue 140, p48	£218
	4K 2 x Nvidia GeForce GTX 970 4GB	www.scan.co.uk	Issue 140, p50	£514

Recommended extra












A discrete sound card gives you higher-quality sound when playing back or recording music.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Creative Sound Blaster Z	www.scan.co.uk	Issue 116, p42	£64

Build a 6-core workstation

Multi-threaded workstation

The parts you'll need to build a PC with serious power in multi-threaded workstation software, such as 3D rendering apps and optimised distributed computing software. The kit list features a 6-core LGA2011-v3 CPU, which is overclockable using the motherboard and cooler listed. Also supplied is 16GB of RAM, 1TB of solid state storage and a 1.2kW PSU, providing loads of headroom for adding multiple GPUs.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Corsair Obsidian 750D	www.scan.co.uk	Issue 123, p30	£133
	Asus X99 Deluxe	www.overclockers.co.uk	Issue 136, p20	£300
	Intel Core i7-5820K	www.overclockers.co.uk	Issue 134, p43	£308
	AMD Radeon R9 280 3GB	www.ebuyer.co.uk	Issue 140, p42	£140
	16GB Corsair Vengeance LPX 2,666MHz DDR4	www.scan.co.uk	Issue 136, p14	£200
	Corsair Hydro Series H110i GT	www.overclockers.co.uk	Issue 140, p17	£100
	Corsair Professional Series AX1200i	www.scan.co.uk	Issue 111, p40	£247
	Samsung 850 Evo 1TB UPDATED	www.cclonline.com	Issue 141, p51	£310
	Seagate Barracuda 2TB ST2000DM0001	www.scan.co.uk	Issue 104, p75	£59
	Lite-On IHAS124-14	www.dabs.com	Issue 99, p108	£10
	Microsoft Windows 7 Professional OEM (or Windows 8.1 if you're using a 4K monitor)	www.ebuyer.com	Issue 75, p46	£110
			TOTAL	£1,917

4K gaming PC










This LGA2011-v3 system can support multiple graphics cards over 28 PCI-E 3 lanes, making it an ideal foundation for high-resolution PC gaming, replacing the graphics card listed above with two high-spec cards. We recommend using Windows 8.1, rather than Windows 7, if you're using a 4K monitor.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	4K 2 x Nvidia GeForce GTX 970 4GB	www.scan.co.uk	Issue 140, p50	£514
			TOTAL	£2,291

Build a mini PC

Core components

The parts you'll need to build either PC. This kit list gives you a solid PSU, 8GB of RAM, an overclockable Haswell CPU, an all-in-one liquid cooler and Windows 7 Home Premium. Also included is a short-PCB graphics card that can play current games at their maximum settings at 2,560 x 1,440, and a 512GB SSD.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Intel Core i5-4690K	www.overclockers.co.uk	Issue 132, p18	£185
	Corsair Vengeance Pro Series 2,400MHz DDR3	www.scan.co.uk	Issue 132, p22	£70
	Corsair H75	www.overclockers.co.uk	Issue 138, p46	£62
	Asus GeForce GTX 970 DirectCU Mini	www.overclockers.co.uk	Issue 139, p20	£290
	Crucial BX100 500GB UPDATED	www.dabs.com	Issue 141, p43	£140
	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£59
	Lite-On IHAS124-14	www.dabs.com	Issue 99, p108	£10
	Corsair CS550M	www.scan.co.uk	Issue 135, p46	£66
	Microsoft Windows 7 Home Premium 64-bit OEM	www.ebuyer.com	Issue 75, p46	£68



Mini-ITX PC

The parts you'll need to build a pint-sized powerhouse.

	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Corsair Obsidian 250D	www.dabs.com	Issue 136, p41	£65
	Asus Maximus VII Impact	www.overclockers.co.uk	Issue 136, p52	£173
			TOTAL	£1,188











Micro-ATX PC

The parts you'll need to build a mini PC that doesn't take up as much room as a full-sized desktop.






	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Fractal Design Arc Mini R2	www.scan.co.uk	Issue 127, p46	£72
	Asus Maximus VII Gene	www.overclockers.co.uk	Issue 133, p18	£160
			TOTAL	£1,182



Cases

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Budget ATX	NZXT S340	www.overclockers.co.uk	Issue 137, p54	£60
	Sub-£100 ATX quiet	Fractal Design Define R5	www.scan.co.uk	Issue 137, p20	£87
	Sub-£100 ATX performance	NZXT Phantom 530	www.overclockers.co.uk	Issue 127, p44	£98
	Air-cooling Sub-£150 ATX	SilverStone Fortress FT05	www.scan.co.uk	Issue 139, p24	£131
	Water-cooling sub-£150 ATX	NZXT H440 Special Edition	www.overclockers.co.uk	Issue 140, p24	£125
	Water-cooling ATX	SilverStone Temjin TJ07B-W	www.overclockers.co.uk	Issue 63, p87	£225
	Mini-ITX tower	Corsair Obsidian 250D	www.dabs.com	Issue 136, p41	£65
	Mini-ITX cube	Antec ISK600	www.overclockers.co.uk	Issue 126, p28	£50
	Micro-ATX	Fractal Design Arc Mini R2	www.scan.co.uk	Issue 127, p46	£72
	Water-cooling micro-ATX	Parvum Systems S2.0	www.overclockers.co.uk	Issue 129, p22	£140

Graphics cards

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	1,920 x 1,080 gaming	AMD Radeon R9 280 3GB	www.ebuyer.com	Issue 140, p42	£140
	2,560 x 1,440 gaming	AMD Radeon R9 290 4GB	www.ebuyer.com	Issue 140, p48	£218
	High-end single-GPU gaming	Nvidia GeForce GTX Titan X UPDATED	www.scan.co.uk	Issue 141, p18	£869
	4K gaming	2 x Nvidia GeForce GTX 970 4GB	www.scan.co.uk	Issue 140, p49	£514
	Mini-ITX	Asus GeForce GTX 970 DirectCU Mini	www.overclockers.co.uk	Issue 139, p20	£290





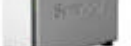
Power supplies

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Mid-range 550W	Corsair CS550M	www.scan.co.uk	Issue 135, p46	£66
	High-end 750W	Corsair HX750i	www.dabs.com	Issue 135, p52	£125
	Mid-range 850W	SilverStone Strider Gold 850W	www.scan.co.uk	Issue 135, p56	£104
	High-end 1.2kW	Corsair Professional Series AX1200i	www.scan.co.uk	Issue 111, p40	£247


Networking

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Router	Asus RT-AC68U	www.dabs.com	Issue 128, p88	£160
	Wi-Fi adaptor	Asus PCE-AC68	www.scan.co.uk	Issue 128, p88	£70


Storage

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Hard disk	Seagate Barracuda 2TB ST2000DM001	www.scan.co.uk	Issue 104, p75	£59
	250GB SSD	Crucial BX100 250GB UPDATED	www.ebuyer.co.uk	Issue 141, p43	£74
	500GB SSD	Crucial BX100 500GB UPDATED	www.dabs.com	Issue 141, p43	£140
	1TB SSD	Samsung 850 Evo 1TB UPDATED	www.cclonline.com	Issue 141, p51	£310
	NAS box	Synology DS215J	www.cclonline.com	Issue 138, p17	£143




Monitors

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	24in monitor	Dell U2414H	www.overclockers.co.uk	Issue 129, p43	£200
	27in monitor (2,560 x 1,440)	ViewSonic VP2772	www.cclonline.com	Issue 129, p60	£604
	29in monitor	Asus PB298Q	www.scan.co.uk	Issue 129, p52	£341
	28in 4K monitor	Asus PB287Q	www.scan.co.uk	Issue 133, p44	£441









Peripherals

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Budget mechanical keyboard	Gigabyte Aivia Osmium	www.awd-it.co.uk	Issue 139, p40	£72
	Mechanical gaming keyboard	CM Storm Trigger-Z	www.box.co.uk	Issue 139, p44	£88
	Mechanical MMO keyboard	Corsair Vengeance K95	www.cclonline.com	Issue 123, p64	£123
	Gaming mouse	Logitech G402 Hyperion Fury	www.currys.co.uk	Issue 139, p53	£40
	Wireless gaming mouse	SteelSeries Sensei Wireless	www.box.co.uk	Issue 139, p61	£99
	Flight stick	Saitek X-55 Rhino H.O.T.A.S.	www.overclockers.co.uk	Issue 131, p29	£155
	Steering wheel and pedals	Thrustmaster TX Ferrari 458 Italia Edition	www.overclockers.co.uk	Issue 137, p32	£220

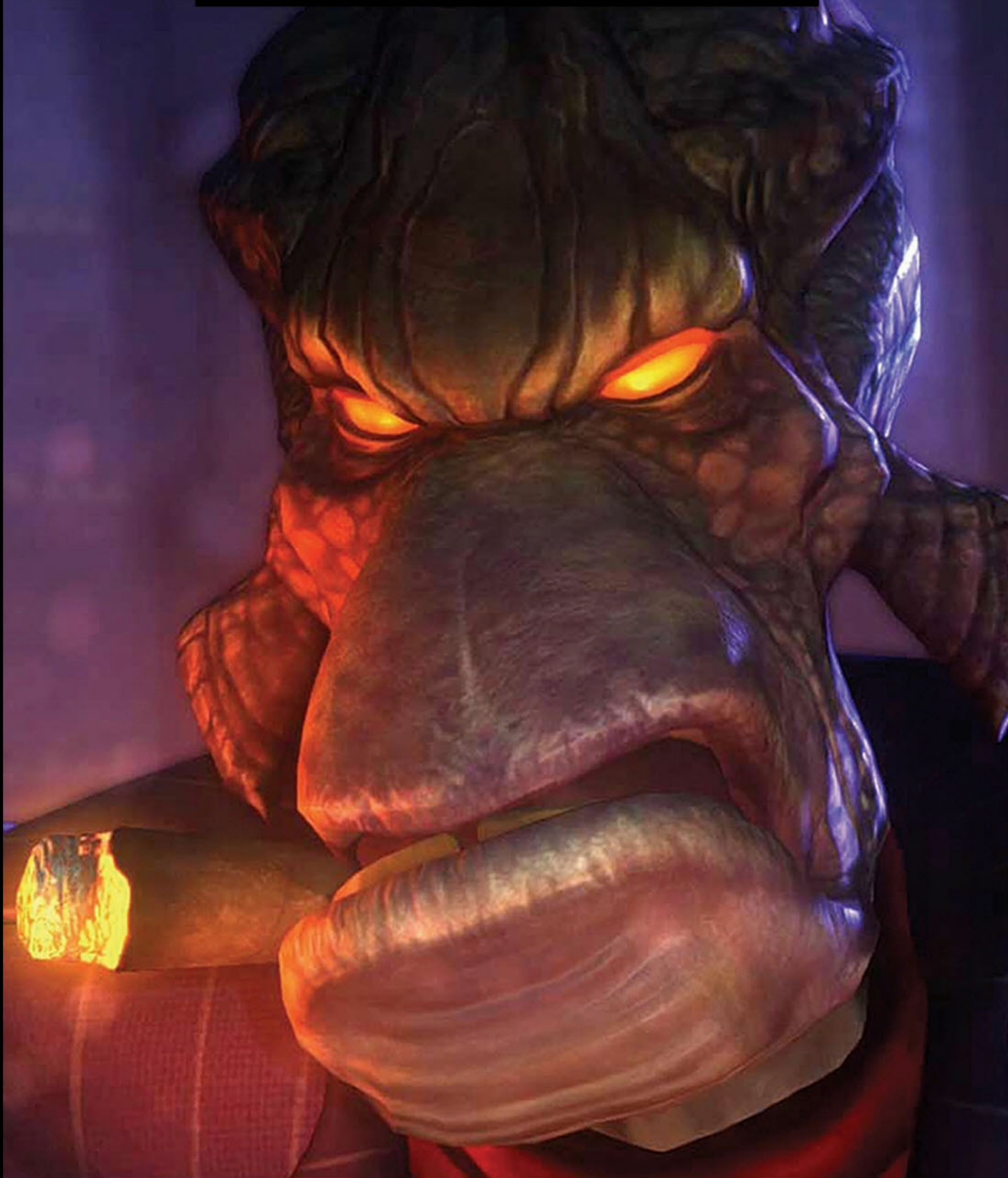
Audio

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	PCI-E sound card	Creative Sound Blaster Z	www.scan.co.uk	Issue 116, p42	£64
	USB sound card	Asus Xonar Essence One	www.overclockers.co.uk	Issue 118, p44	£363
	2.1 speakers	Corsair SP2500	www.scan.co.uk	Issue 118, p75	£173
	Headset	HyperX Cloud II UPDATED	www.ebuyer.com	Issue 141, p32	£75

Systems

	TYPE	NAME	SUPPLIER	FEATURED	PRICE (inc VAT)
	Budget gaming PC	Scan 3XS Z97 Performance GT	www.scan.co.uk	Issue 133, p60	£599
	Quiet gaming PC	Chillblast Fusion Serenity	www.chillblast.co.uk	Issue 138, p66	£1,499
	Dream PC	Scan 3XS Bear	www.scan.co.uk	Issue 125, p58	£6,999
	Devil's Canyon gaming PC	Scan 3XS Z97 Performance GTX	www.scan.co.uk	Issue 136, p60	£1,199
	4K gaming PC	Overclockers Infin8 Nebula UPDATED	www.overclockers.co.uk	Issue 141, p58	£3,116
	Micro-ATX gaming PC	AWD-IT Chimera i5 Dead Silence Gaming PC	www.awd-it.co.uk	Issue 135, p64	£949
	Gaming laptop	MSI GT70 2PC Dominator	www.overclockers.co.uk	Issue 129, p26	£1,320
	Haswell-E PC	Scan 3XS X99 Cyclone SLI	www.scan.co.uk	Issue 134, p60	£3,349

Games



Featured this month

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RICK LANE / INVERSE LOOK

HARD WORK? HARD CHEESE

Rick Lane is tired of developers whining that making games is hard

A rift has appeared between developers and critics lately. The cracks appeared with a wave of questioning articles directed towards Peter Molyneux, designer of *Syndicate* and *Dungeon Keeper* who, in recent years, has become increasingly known for his enthusiastic overpromising and subsequent failure to deliver.

This time, the subject was his crowdfunded god game *Godus*, which has been a scene of development troubles and reneged promises since its announcement two years ago. Unlike Molyneux's previous projects, *Godus* sees consumers' money on the line, leading to him being scrutinised closely by several journalistic outlets. In a fiery interview with *Rock Paper Shotgun*'s John Walker, Molyneux attempted to defend his position. A large part of his argument was that making games is hard, and development doesn't always go as planned.

Afterwards, several other developers, including *Duke Nukem* creator George Broussard, came out in defence of Molyneux by making similar statements: game development is really tough and critics don't understand the difficult decisions developers have to make in private. Broussard's latter point is particularly asinine. How can critics possibly be expected to understand decisions made in private company? More generally, this whole defensive tactic of appealing to artistic struggle simply doesn't cut it for several reasons.

Firstly, *of course* making games is hard. Doing anything creative is challenging, be it making a film, writing a novel or developing a game. But the difficulty has no bearing on the quality of art. The *Transformers* movies, widely regarded as abysmal, still required incredible organisational skills and thousands of man-hours working on CGI effects to make them

possible, while *E.L. James* had to type 105,000 critically panned words in order to write *Fifty Shades of Grey*. And who can forget *Duke Nukem Forever*, a game that spent 12 years being designed, redesigned, cancelled and reinstated, only to emerge as an embarrassing mess?

Creative challenge isn't an excuse for lousy art, and such reasoning is egregious when referring to game development, because making games is easier than ever. Three decades ago, developers had extremely limited tools with which to work; hardware capable of only producing 2D sprites or 3D wireframes, an often inaccessible distribution infrastructure, no crowdfunding models and little third-party technology to help.

Nowadays, there are countless ways to fund and build games. Tools such as *GameMaker* allow pretty much anyone to give it a stab regardless of programming prowess, while third-party engines such as *Unreal*, *Unity* and *Source* are being given away by their creators, as announced by all three engine makers at

this year's GDC. In addition, dozens of publishers, old and new, exist alongside new funding models such as *Kickstarter*, *Patreon* and *Steam Early Access*. It can't even be argued that players are more demanding in their tastes, as simple games such as *Hotline Miami* happily co-exist alongside big-budget blockbusters such as *Assassin's Creed*.

Whining about the difficulty of game development makes developers look like childish amateurs, especially figures such as Molyneux and Broussard, who have been developers for decades and have profited enormously from their profession. Don't be fooled by developers playing the victim of their own creative strive; it makes little difference to the quality of the art, and they've never had it so good. **EPG**

The defensive tactic of
appealing to artistic
struggle simply
doesn't cut it



Cities: Skylines / £22.99 inc VAT



DEVELOPER Colossal Order / PUBLISHER Paradox Interactive / WEBSITE www.citiesskylines.com



The latest SimCity game was brimming with ideas, but let down by some startling design decisions. Overly restrictive building plots resulted in ridiculously small 'cities', a system that only existed to facilitate forced multiplayer interaction that few people wanted. Meanwhile, the game's ostensibly detailed simulation was let down by a hive of bugs and a progression structure that very quickly ran out of steam. Just shy of two years later, and Colossal Order's Cities: Skylines has dropped its suspiciously similar planning permission leaflets through our letterbox.

Skylines is a cocky little game. It doesn't merely ride the coat-tails of SimCity – it takes the whole coat and runs off giggling. With SimCity looking on agog, Skylines then patches up all the holes in the fabric, resulting in a far more wholesome and satisfying game.

Skylines begins with little preamble. After selecting the landscape to ruin with your impending urban sprawl, you're immediately dropped into a huge plot of land where you can begin construction.

Skylines' freedom to build is an obvious reaction to SimCity's restrictiveness, and as a statement of intent, it works. Looking over all that glorious, untapped land sends

your mind into a frenzy of imaginative blueprinting. What's more, as the game progresses, you can purchase adjacent plots of land, expanding your city by up to eight times the size, spreading it across highways, over rivers, and into areas that contain precious natural resources.

However, money isn't as plentiful as space. Attempting to build a road network that encompasses just that initial plot will empty your wallet faster than a Swedish cocktail bar. Successful city building in Skylines doesn't require making the most of every square inch of ground, but it does involve carefully considered expansion. Starting off with a few roads and the basic residential, commercial and industrial zoning permits, you plot out a small town. After creating a pipeline to a nearby water supply and some rudimentary power generation, people will slowly migrate to your newly founded urban centre.

Upon reaching certain population milestones, you unlock additional services such as schools, fire stations and police stations, which enable you to attract more people, bring in more money and further expand your city. As your city grows into a bustling metropolis, you'll be building towering skyscrapers and sprawling airports, and the streets will be thick with people going about their business.





It's a straightforward progression ladder, but it's also an engaging one. There's always something to do, and always a new goal to which you can aspire. At the same time, you're spinning multiple plates to keep the city functioning – expanding water pipelines, extending services to new areas, juggling finances and implementing new laws.

This latter feature is where Skylines gets particularly interesting. The game lets you divide your city into districts, and enact laws and regulations that only affect those districts. For example, you might want to ban heavy traffic in a quaint residential area, or allow recreational drug use in a certain area downtown. Districts also play a crucial role in specialising your city. You can regulate industrial zones to focus on specific industries such as agriculture, mining or forestry, or ban certain areas from building low or high-rise structures. Unfortunately, you can't instruct services to only cover certain districts, which seems like a missed opportunity for ensuring that every area receives appropriate fire protection or police patrols.

In terms of simulation, Skylines is detailed but not massively deep. You can watch service vehicles such as fire trucks or hearses zoom around the city putting out fires and picking up corpses, and follow individual citizens as they go to work, chat outside their homes or go downtown. It's fun to sit back and enjoy the various moving parts, especially when you access more advanced transportation systems such as overground and underground trains, as well as airports. On the other hand, economy management is very simplistic. There's a hard line in taxation between happy and unhappy citizens, and although this system makes it easy to make money, it isn't particularly satisfying.

Traffic management is undoubtedly where the simulation is deepest, which isn't surprising given that

Skylines is made by the developer of Cities in Motion. Build too many small roads without sufficient alternate routes, and traffic will back up. It's also important to ensure there are multiple modes of transportation available. Connecting your residential areas to your commercial and office areas using bus routes and metro-tunnels is a good way to ensure that shops have plenty of customers and offices have an available workforce.

Skylines exhibits a few flaws though. Initially, manually placing water pipelines and bulldozing abandoned housing is fun, but it

becomes hard to keep up with this work as your city grows, and it's annoying when your population growth plummets because a tiny residential district is (understandably) unhappy about its lack of water. A simple solution would be to include water and demolition services that automate these processes, and become available once your city reaches a certain size.

Also, there's currently a bug, which means that people moving into a new area spawn at the same age, meaning they all die in big groups. This situation results in piles of bodies rotting in apartments as your undertakers desperately try to ferry them to their graves. Grisly.

More generally, Skylines doesn't possess much personality of its own. Not only does it function in much the same way as SimCity, with similar mechanics and UI, it also adopts a near identical aesthetic, right down to the unpleasant blurring effect that occurs when you zoom in close to your city. This lack of a personal stamp doesn't impact hugely on the game's overall quality, but it does sell the game short.

While Skylines undoubtedly owes a lot to SimCity, it builds on that template in impressive ways and it should embrace those unique qualities, rather than resorting to such cheap visual copycatting.

For the most part, though, Skylines excels. Witnessing your city's buildings gradually cram closer together and claw higher into the sky is immensely satisfying. Skylines already has extensive community support too. Modders are busy creating new buildings, fixing problems and adding new systems. Hopefully, the community's engagement will extend the game's lifespan considerably, and make it remembered for more than being the game that stood on the shoulders of SimCity. It certainly deserves it.

RICK LANE



It doesn't merely
ride the coat-tails of
SimCity, it runs off
with the whole coat



OVERALL SCORE

87%

/ VERDICT

Skylines may look like a shameless SimCity copycat, but it improves on Maxis' troubled sim in almost every way.

Hotline Miami 2: Wrong Number / £14.99 inc VAT

DEVELOPER Dennaton Games / PUBLISHER Devolver Digital / WEBSITE www.devolverdigital.com/games/view/hotline-miami-2-wrong-number

Hotline Miami was an intoxicating cocktail of psychedelic visuals, with a pulsing soundtrack, a cleverly ambiguous narrative and blistering, astonishingly violent action. It bypassed the rational, conscious parts of your brain and hooked straight into your nervous system, being all about reflexes and moment-to-moment thrills. Like Portal, Hotline Miami felt like bottled lightning, so attempting to recapture such fleeting electricity seems foolhardy. Portal 2 showed you can at least build a machine that generates a similar voltage, though, and Hotline Miami 2 attempts a similar feat.

OVERALL SCORE

58%

/ VERDICT

Dennaton's storytelling ambitions push Hotline Miami beyond the limits of its capabilities, resulting in a baggy and confused game that frustrates as often as it thrills.



The original Hotline Miami focused on a character called Jacket, who received strange phone calls commanding him to break into buildings occupied by the Russian Mafia and kill everyone inside. Wrong Number is both a sequel and a prequel, with an ensemble cast. Its story follows roughly a dozen perspective characters, including a group of copycat thugs emulating Jacket's murders, a detective and a journalist looking into Jacket, an actor playing Jacket in a film and a contact of Jacket's who was involved in a guerrilla war years before the incidents in the sequel take place.

If that last paragraph made you go cross-eyed, don't worry. Hotline Miami 2's story is, to put it simply, baffling.



Oddworld: New 'n' Tasty! / £14.99 inc VAT

DEVELOPER Just Add Water / PUBLISHER Oddworld Inhabitants / WEBSITE www.oddworld.com/oddworldgames/new-n-tasty/



Remastered games don't get much better than this beautiful update of the platform classic, Oddworld: Abe's Oddysee. Most remasters essentially configure the game to run at higher resolutions, while providing sharper textures and enabling more modern graphical effects. But Just Add Water has gone further, completely rebuilding the game in the Unity engine.

Abe's Oddysee's flat, pixelated environments have been redesigned in chunky, vibrant 3D, while its levels are no longer split into separate, static screens. Instead, each area is seamlessly connected, and Abe's traversal across them is tracked by a scrolling camera that tilts and zooms to give the best possible view.

You may think such dramatic alterations would risk damaging the game's feel, but Just Add Water has ensured that the experience retains the overall aesthetics of the 1998 original. Animations, sound effects, and the design of characters and environments have been recreated with precision. The rusty corridors of Rupture Farms and its silhouetted stockyards are precisely as you remember them.

Just Add Water has made a few embellishments. Abe's big, yellow eyes are much more visible than



before, and he's much more animated during the game's trademark 'Gamespeak' conversation, but these are welcome added details rather than major alterations.

Most importantly, New 'n' Tasty retains the delicate balance of slapstick humour and satirical observations of the original. Fart jokes abound, and the many messy ways in which Abe can meet his demise are still both shocking and amusing. But beneath the veneer of silliness is a more serious commentary on capitalism's exploitation of its workers, and destruction of the environment for profit.

Abe's Oddysee moulds many different components together into one seamless whole, tackling multiple subjects with a delicately judged tone, in a fictional world

OVERALL SCORE

90%

/ VERDICT

One of the best remasters around, Oddworld: New 'n' Tasty breathes fresh life into Abe's Oddysee.

Not only does it spread itself far too thinly, but it's told using endless flashbacks and flash-forwards, making the chronology of events almost incomprehensible. Any of the characters would make a great protagonist, but Wrong Number's use of all of them makes it difficult to stay interested in any single plot thread.

This convoluted crime saga has further ramifications for the game. Hotline Miami 2 is over twice as long as the original, and it struggles to maintain this length. During play, it's very similar to the original game. It makes a few additions, such as being able to play as two characters at once, which is an interesting tactical challenge.

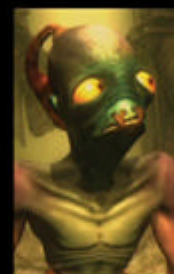
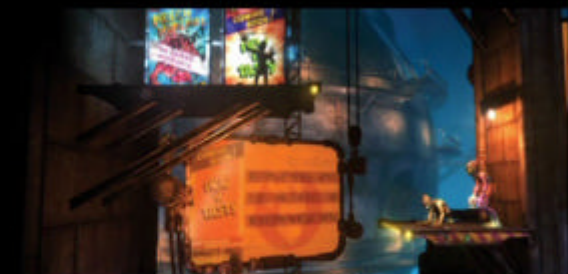
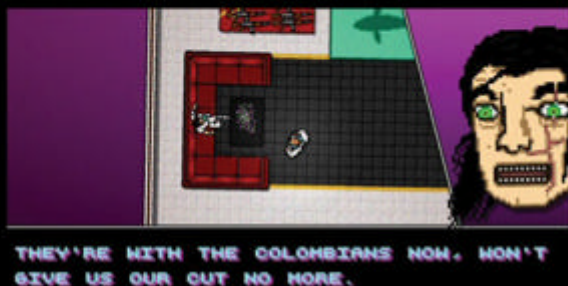
More often than not, though, Wrong Number mixes up the game by limiting rather than expanding your options. At least half the playable characters don't use the trademark masks that provide unique strengths and weaknesses, while the Hawaii flashback missions limit you to a single-ranged weapon and a knife. This setup undermines the



ad hoc fun of grabbing whatever weapon presents itself in the moment, which is crucial to Hotline Miami's combat.

There are still some fantastic individual missions, including a bank heist and a prison escape, and the intensely twitchy, reactive combat is as enjoyable as ever. But the overall quality of Wrong Number is inconsistent, demonstrating that bigger isn't always better.

RICK LANE



where the wildlife and inhabitants are uniquely alien, yet it all makes perfect sense within the game's context. The robotic Sligs are a prime example, being cyborg thugs with Cthulhu-like mouths; however, they also sport heavy machine guns and have their own burp-beat theme tune.

As a platform game, it's as difficult as ever. The jumping puzzles are some of the trickiest around, although Just Add Water has introduced a generous checkpoint and quicksave combination. The new gamepad control system is less

helpful though. It's fine for the most part, but the analogue controls are too slippery for the game's more demanding puzzles. That said, it can be reconfigured to use the traditional control method, or you can just use a keyboard.

Aside from these minor control issues, New 'n' Tasty gets little wrong. It's a remaster made with consideration and love. If you fancy a weird, funny and challenging adventure, Abe is the man to follow.

RICK LANE



White Night / £10.99 inc VAT

DEVELOPER Osome Studio / PUBLISHER Activision / WEBSITE <http://osome-studio.com/en/whitenight>

White Night has a fantastic premise, combining a traditional haunted mansion with 1930s noir fiction. It sports one of the most striking visual styles we've seen in years, and an intriguing mystery. You play a man involved in a car crash after seeing a vision of a woman in the road. Injured during the impact, he seeks medical aid at a nearby gothic mansion. Ignoring the warning signs of an impending horror narrative (creepy family graveyard, nobody home, muddy footprints leading into the house and trailing off) he enters the house, and is drawn into the tragic and bloody tale of the family who owns it.

It plays a bit like Resident Evil, but without guns or zombies. White Night is mostly about puzzle solving and storytelling, overlaid with the game's one original mechanic – its use of light. The splendid monochromatic art style has more behind it than aesthetic pleasure. You can literally lose yourself in those pitch-black shadows. Stay too long and your sanity will crumble, signified by intensifying music and a vibrating camera.

To prevent yourself from losing your sanity in the dark, you need to use whatever light sources you can find. Electric lights are the safest; many of the puzzles involve locating unplugged lights, or manoeuvring lamps so the light shines in particular areas. Otherwise, you'll need to fall back on your matches. You can only

carry 12 matches at one time, which makes about as much sense as a rubber helicopter, but the arbitrary limitation adds to the tension, especially when a match fails to strike.

There's more to fear than the dark, however. White Night's story traces the Vesper family's gnarled family tree – the syphilitic industrialist Henry, his devout wife Margaret, their son William and his Jazz-singer lover Selena. Margaret is the primary antagonist. Her grey shade still stalks the building, attacking anyone who comes near. As the story progresses, however, you realise that Margaret isn't the worst of this brutish bunch.

Your relationship with Margaret, and indeed all the Vesper family, has the makings of a cracking ghost story, but the script frequently derails the game's tone. Its imitation of a noir-esque narrator is clumsy and laden with tortured similes. The Vespers' diary entries fare better, but they're littered with spelling mistakes and missing words, compounding the amateur writing. Worst of all, the introduction and conclusion are particularly poorly penned, so you start off on the wrong foot and end with a bitter taste.

Good writing is crucial to capturing a noir theme, and White Night's failure to do so damages it. Still, in its quieter moments, White Night is a tense and stylish horror adventure, and its low price still makes it worth playing if the art style and premise appeals.

RICK LANE

OVERALL SCORE

67%

/ VERDICT

White Night has a great atmosphere and a potentially compelling plot, but it's let down by clunky writing.

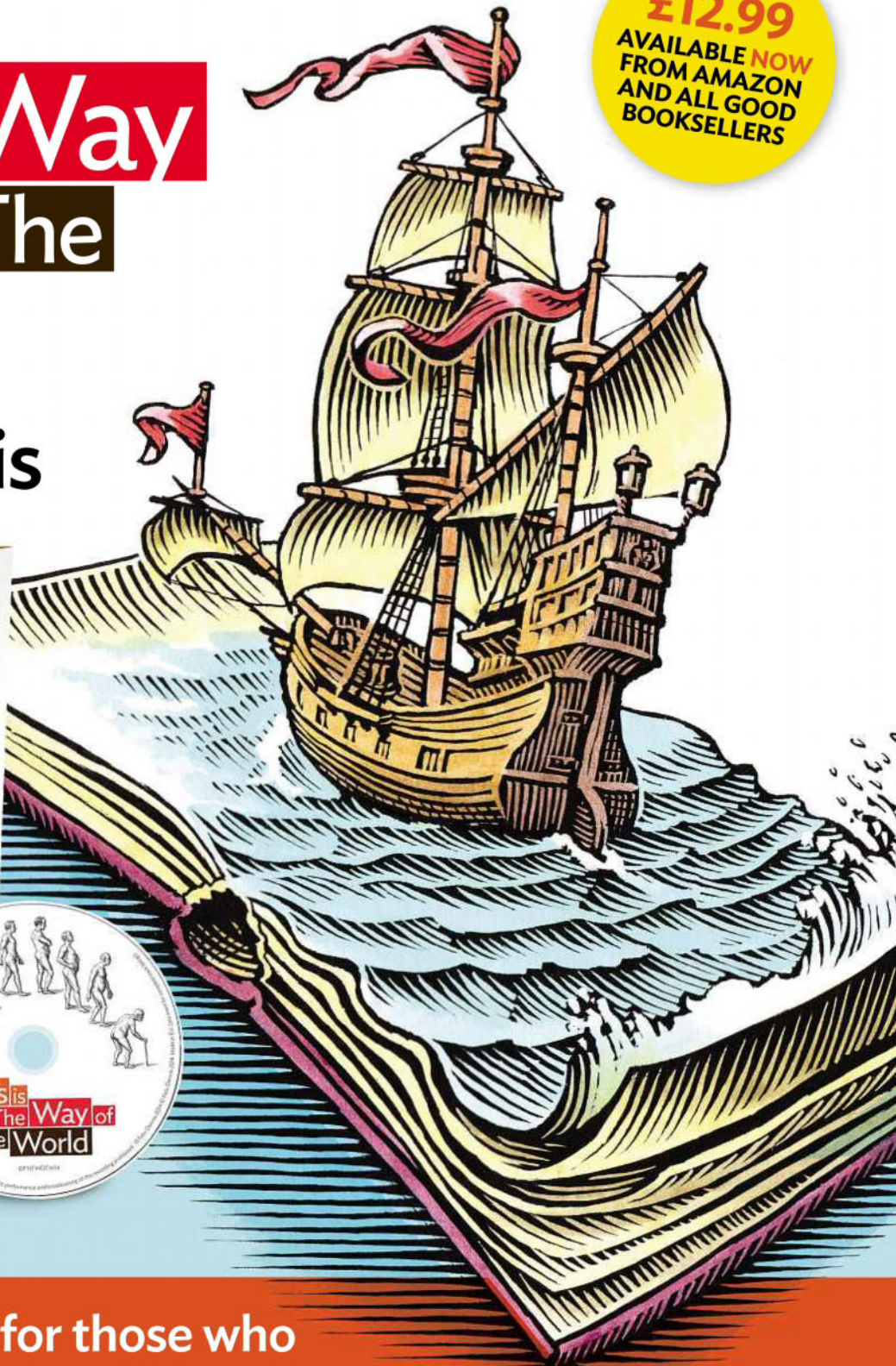
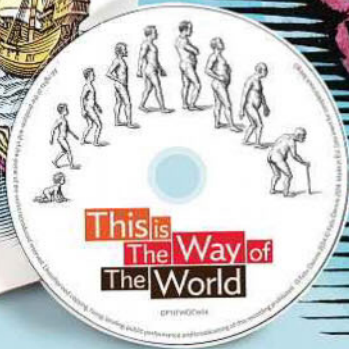
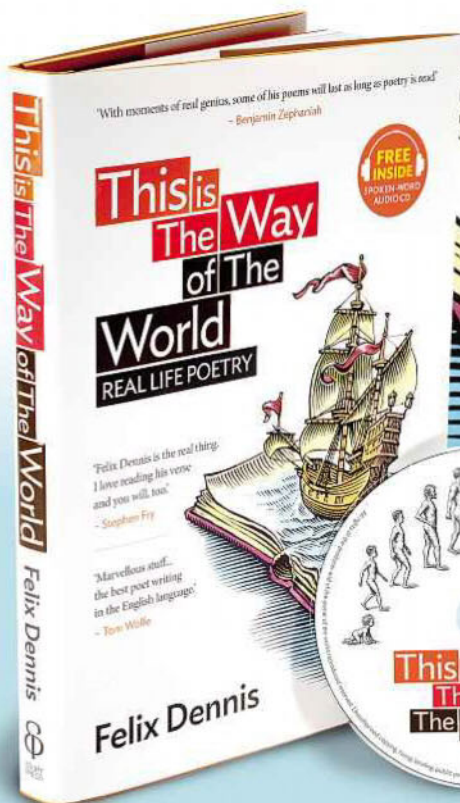
'With moments of real genius, some of his poems will last as long as poetry is read.'

– Benjamin Zephaniah

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RICK LANE / THE ENGINE ROOM

Asura

Rick Lane steals the plans for Rebellion's long-standing homespun tech behind the Sniper Elite series and the Alien vs Predator reboot

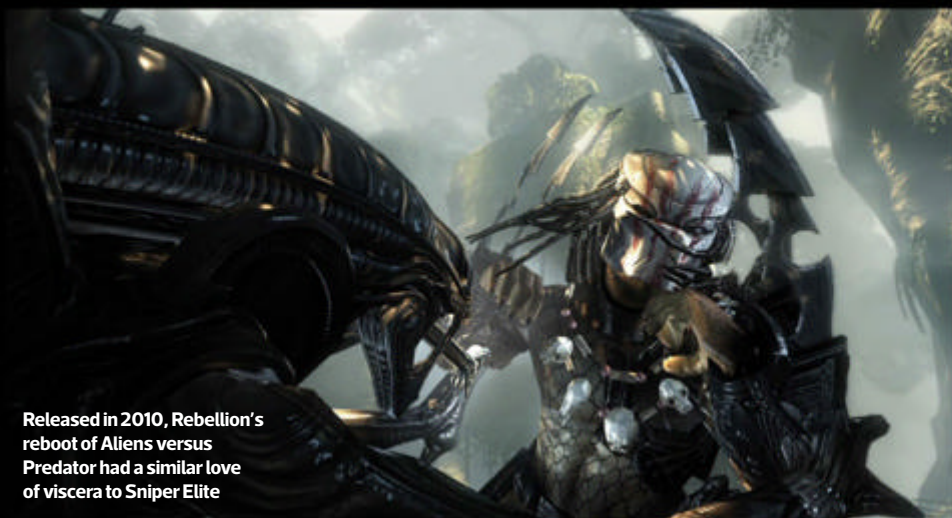
Asura has quietly done its own thing for a long time, and has consequently accrued an impressively eclectic array of features. The in-house technology of Rebellion software, creator of the Alien vs Predator and Sniper Elite games, alongside many others, Asura has been the basis of roughly 40 Rebellion titles in the past 15 years.

'The Asura engine started its life towards the end of 1999, after the original Alien vs Predator was completed,' says Kevin Floyer-Lea, head of programming at Rebellion. An employee there for almost 20 years, Floyer-Lea has been working with Asura for the entirety of its existence. 'This was around the time that the "next-generation" PlayStation 2 was being unveiled to developers, followed later by the original Xbox. So the main goal for Asura was to create a scalable, truly cross-platform engine without compromising PC support.'

Asura was an early adopter of the concept of a game engine as a complete package of game-making tools, rather than a disparate assortment of graphics renderers and utilities. Back then, the collective executable for all the subsidiary function was simply known as Tools. 'Artists and designers would be able to see things rendered exactly as they would be in-game, and play the game directly in Tools whenever they wanted to test things,' Floyer-Lea explains.

'This probably all sounds quite logical and commonplace now, but it definitely wasn't the industry standard 15 years ago!'

In its lifetime, Asura has powered a wide variety of games. Alongside its most well-known series Sniper Elite,



Released in 2010, Rebellion's reboot of Aliens versus Predator had a similar love of viscera to Sniper Elite



With the player wreathed in shadow, you get a good contrasting sense of the harsh desert light radiating off these old city walls

Asura has provided the foundation for games based on Judge Dredd, Harry Potter, James Bond and even The Simpsons game.

One of Floyer-Lea's biggest challenges over the years has been keeping the engine flexible enough to adapt to different titles.

'There's a definite black art in trying to improve the engine with each game, but also not narrowing down or restricting the kind of games we can make in the future,' he says. 'A sniping game, where the player can suddenly zoom in and make something hundreds of metres away completely fill the screen, can create real headaches for features such as shadow rendering or texture

streaming, which a general FPS might be able to ignore.'

Most recently, Asura has enjoyed a little time to focus its tech, specifically on Rebellion's Sniper Elite games. One of Sniper Elite's more novel features is its X-Ray technology, which shows the damage caused by a sniper's bullet in graphic detail as it passes through an opponent's body. While undoubtedly gruesome, X-Ray also posed a few interesting technical problems. Such detailed models require a high polygon count, so they can't be simulated at all times.

Instead, as Floyer-Lea describes, 'there's a special effect that stencils out the X-Ray volume when rendering the normal character model, and then the internals are rendered later.' In addition, lighting a person's skeleton and organs proved to be quite difficult.

'We don't want it to stand out too much from the surrounding lighting, but at the same time, we need to ignore certain shadows and so on, which is awkward with a deferred lighting engine.'



Rebellion's Judge Dredd game, *Dredd vs Death*, was one of the earliest to be powered by Asura

On the subject of lighting, *Sniper Elite III* saw some significant changes to the engine's approach to light and shadow. Because the game is set in North Africa, Rebellion wanted to give players a sense of the blazing desert sun above them. 'For the direct lighting component of the sunlight we stuck to a fairly standard approach, with a cascade of shadow maps so that everything had shadows that updated in real time. However, we also had a pre-baked system for the potential bounced light coming from the sun, and the direct and indirect lighting coming from the sky.'

In addition, Rebellion used a form of Precomputed Radiance Transfer (PRT) to calculate all the potential direct and indirect light sources in *Sniper Elite*'s levels; for static objects, these are stored in directional lightmaps as third-order spherical harmonics. In (very) simplified terms, this means the radiance of a particular light (direct or indirect), is defined across a sphere's surface.

'This allows artists to set a sunlight direction in Tools and automatically get several bounces worth of indirect light with soft shadows across the whole environment. So while the irradiance data itself is pre-baked, the outputted indirect lighting can vary dynamically based on the sun direction and sky properties.' For dynamic lights, Rebellion used light-probes, which provide a more efficient way of simulating real-time light and shadow.

Sniper Elite III also saw the debut of Rebellion's bespoke Obscure

Fields tech, which is designed to affect characters standing in complete shadow, so they don't project a shadow themselves, but they're affected by soft shadows and indirect irradiance. 'Each character has a simplified representation made of ellipsoids that move with the model's animations, and we have a compute shader that can perform analytical ray tracing against these volumes and modify the irradiance of surrounding geometry as part of the deferred lighting pipeline.'

This system, according to Floyer-Lea, gives characters consistent soft-shadowing onto objects and even onto themselves. 'The beauty of the Obscure Fields tech is that it not only gives us soft directional shadows from the characters on any surrounding geometry, but it also gives characters natural self-shadowing, such as an arm moving against a body, or the chest becoming more occluded when you crouch.'

Another major change between *Sniper Elite V2* and *Sniper Elite III* was the major increase in level size, which means *Sniper Elite III* allows

The anatomical X-Ray shots are too detailed to be simulated constantly

Look closely and you can see Obscure Fields at work, as this unfortunate soldier's arm casts a shadow on his chest.



for more tactical options when scouting and sniping. Floyer-Lea claims that Asura never had a problem with rendering larger environments, thanks to its multi-threading and occlusion culling (removing off-screen objects from the rendering pipeline). However, populating those larger maps with lots of animated characters did prove technologically burdensome. 'That necessitated a large rewrite to multi-thread some aspects that had previously been single-threaded, as well as optimising the animation blending code itself.'

The future of Asura is potentially very interesting. Last year, Rebellion threw its weight behind AMD's performance-boosting Mantle API. 'We'd been asking for a lower-level API for PC GPUs for many years, and Mantle was exactly that, so it was a natural fit for us,' Floyer-Lea states. However, DirectX 12 and Vulkan are both prioritising similar performance improvements, and DirectX 12 has a wider probable install base too. Is this likely to affect Asura in any way? Floyer-Lea doesn't believe so. In fact, he believes Rebellion's adoption of Mantle will prove an advantage. 'Those APIs are built on exactly the same principles as Mantle, so it's given us a real head start. Internally, we still use Mantle to compare performance with our early DirectX 12 builds.'

Either way, it's unlikely Asura will go anywhere soon, having been constantly iterated for the past 16 years. 'It's all about having the restraint to recognise that a system may not be perfect but does the job required if we give it a few tweaks, while at the same time not being afraid to start again from scratch when the situation really demands it,' Floyer-Lea concludes. **CPC**

CUSTOM PC MAKES A VIDEO GAME

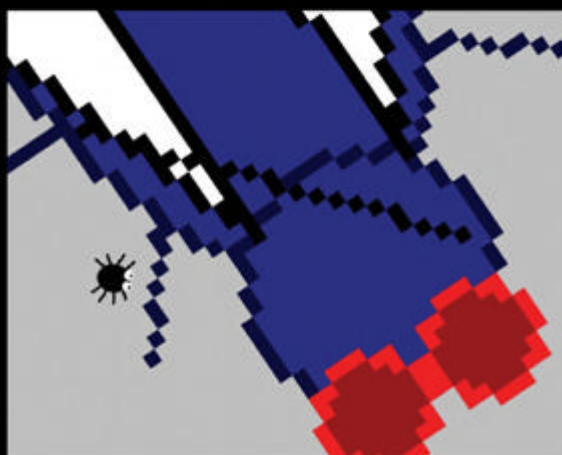
PART ONE

Can you make a video game from scratch with no experience, and a dubious amount of talent? Rick Lane explores getting started in game development

This month, we decided to have a go at making a video game ourselves, and relate our experiences. We're starting with no prior experience in game development, and no clue what we're going to make, so the chances of us creating the next Minecraft are unlikely. But the point isn't to create a masterpiece. Rather, it's to show that today's game-making software, combined with an abundance of helpful instructions online, mean that anybody can have a try.

We'll be relying on two crucial products. The first is GameMaker Studio, an accessible game engine and development kit designed for building simple 2D games. The other weapon in our developmental arsenal is an excellent series of YouTube tutorials created by Gunpoint developer Tom Francis. Initially, we'll be following his instructions fairly closely. Both resources are freely available (although a more powerful version of GameMaker can be bought). If you want to have a go yourself, getting started takes all of half an hour.

Francis' tutorial focuses on a top-down shooter in the vein of Hotline Miami (also a GameMaker game), although it's much more simplistic. The initial video is simply about creating a playable game space, an object for the player to control and programming those controls directly using GameMaker's scripting



OH GOD, WHAT HAVE WE DONE?

language. GameMaker's playable spaces are known as 'rooms,' while raw objects take the form of invisible nodes placed in the game world. More often than not, objects are connected to a visible sprite, which then has actions applied to it, either through using lots of pre-designated visual icons and menus, such as 'move' or 'shoot,' or by coding those actions directly.

What becomes apparent within the first half-hour of game-making is that our caveman-like artistic abilities are going to limit the scope. It doesn't help that GameMaker's sprite editor is much more like MS Paint than Photoshop. You can't separate your images into layers, which makes it hard for a novice to draw any picture more complicated than an amorphous blob.

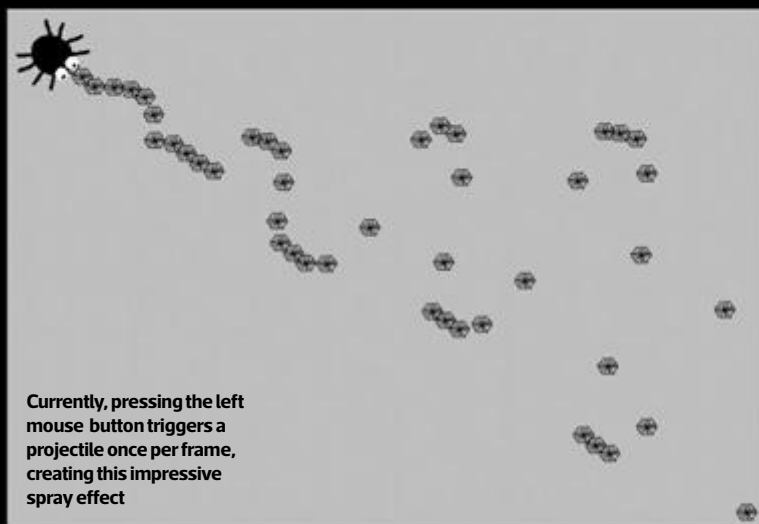
At this stage we're more interested in learning basic coding than becoming the next da Vinci, though, so we proceed with the player as a blob, which is also how Francis proceeds in his example. We then program some WASD controls to make the blob move around. At this point, an idea arises that will go on to define our entire game. My fiancée is looking over my shoulder while I work, and suggests that, instead of a blob, we should draw a spider. Since a spider is basically a blob with legs, this job is possible even with our primitive doodling skills. We also



In our game's most advanced state, the spider grows when it eats a fly



Telling a sprite to spawn when the mouse is pressed results in a paintbrush effect



Currently, pressing the left mouse button triggers a projectile once per frame, creating this impressive spray effect



We changed the projectiles to fire from the spider's abdomen, and trap the fly in a web

give the spider eyes so we can see what direction it's facing.

The spider theme will dictate many of the following design choices, and it's at this point that our game stops being a carbon copy of Francis' tutorial game, assuming an identity of its own.

For example, part two of Francis' series covers shooting. It describes how to make the player's direction follow the mouse cursor, bind a projectile to the mouse button (which initially turns the mouse into a paintbrush, enabling us to write the 'hello' in the left screenshot), and finally how to make that projectile 'fire' from the player's sprite.

Since we're playing as a spider, it's logical that our spider would fire silk webs. However, a spider spins silk from its abdomen, so we tweaked Francis' projectile tutorial code 'MyProjectile.direction = image_angle' to read 'MyProjectile.direction = image_angle - 180', which makes the spider webs fire 180 degrees opposite from the angle the spider is facing. This tweak adds an interesting spin on the top-down shooter formula, as it means we can

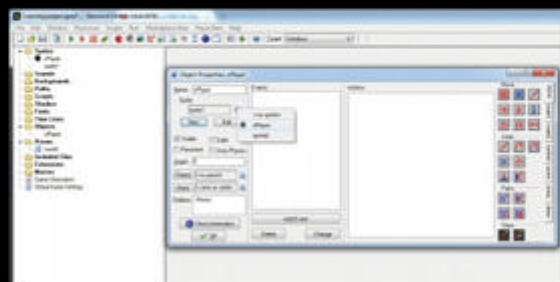
only shoot enemies while facing away from them.

However, before we can shoot any enemies, we first need an enemy to shoot. Again, the spider theme dictates the logical adversary – a fly. So we drew a fly sprite, which although still terrible, is a far better fly sprite than we imagined we could draw, and then followed Francis' instructions to give it a rudimentary movement AI. This movement system tells the fly to bounce off the game's window border, reversing its direction when it collides.

Francis' next step covers projectile collision and destruction. In his game, the enemy displays damage by shrinking and then disappearing, and we experiment with this idea for learning purposes. At this point, we also encounter our first bug – the fly shrinks when damaged and then, when it reaches a size of zero, starts shrinking by minus numbers, meaning it grows into an absolutely enormous insect horror.

A shrinking fly doesn't align with our spider theme anyway. It would be better if our spider could trap the fly with its web, then eat it. What we quickly learn about coding is that if you can program an object to do one action, it's usually very easy to figure out the opposing command. Since we can tell the fly to move, we can command it to stop, and as we can program a sprite to disappear, we can code a sprite to appear.

Accordingly, we created a separate, larger web sprite, and programmed the fly to spawn it underneath itself when it gets hit by the spider's



Objects can be assigned sprites, commands and scripts

projectile. At the same time, we also programmed the fly to stop moving when it's struck by the spider's projectile, which simulates the effect of the fly being trapped by the spider's incoming web. We then instruct the fly to destroy itself when it's touched by the spider, but *only* if it has stopped moving (another interesting point – enemies *do a lot* of work for your game). Ideally, we eventually want the fly to register the lack of movement *and* the existence of the web sprite, but the former on its own will do for now.

The final feature we want for our game right now is a sense of continuation and progression. Francis explains how to make an enemy randomly spawn another enemy when it's destroyed, which will suffice for continuation. For progression, we took inspiration from the giant fly bug earlier, and made our spider grow slightly when it eats a fly (in more literal terms, we program the fly to *grow* the spider when the fly destroys itself. Again, the fly is doing a lot of work for us).

And there we have it, the basic foundation for a game, and it was all achieved in just two evenings! What's most surprising about our experience so far is just how much variety can be created when you understand just a few basic commands. Simply following our theme to its logical conclusions has already resulted in some notable diversions from the tutorial, and we were able to figure out the right code for all of them. Even at this stage, we'd heartily recommend experimenting with GameMaker, and Francis' tutorials offer the perfect way to get started.

But while our game might have an identity, it isn't much fun to play yet. In the next part we'll focus on adding spectacle to our spidery shooter, and giving it a little more structure. **CPC**



JIM KILLOCK / DIGITAL RIGHTS

The cost of privacy

Jim Killock analyses the Privacy and Security report from the UK's Intelligence and Security Committee

The mammoth Privacy and Security report from the UK's Intelligence and Security Committee (ISC) is an object lesson in how the establishment works. Faced with overwhelming evidence of a vast extension of surveillance powers, it's a call for rationalised laws and greater explanation of what GCHQ is doing.

It's a remarkable report. The ISC might never admit it, but the report owes its existence to Edward Snowden. Faced with detailed information about precisely what GCHQ is doing, the ISC has been forced to respond with its own description, including a lot of reassuring words that explain that its work is necessary, proportionate and lawful. In between, it makes some startling admissions: firstly, that 'bulk personal datasets' exist and are largely legally unregulated; and secondly, that the choices of technologies that underlie GCHQ's Internet break-ins lack any democratic oversight.

The ISC is a 'Parliamentary' committee. Until now, it's been appointed by the Prime Minister. In the future, the Prime Minister will draw up a list of acceptable candidates, and Parliament will appoint the committee from that list. The argument is that the head of

government must ensure the members are trustworthy, as they will see secret material. However, in practice, it means the PM can select people whose views are sufficiently close to those of the agencies. The current ISC is dominated by a mix of trusted hands, such as former Cabinet Secretary Lord Butler, along with Hazel Blears and former Foreign Secretary Sir Malcolm Rifkind. Nobody on the committee could be said to be a sceptic.

It makes some startling admissions: that 'bulk personal datasets' exist and are largely legally unregulated

In other countries, including the USA, oversight committees are directly elected by democratic representatives, and some of the committee members include leading critics.

The result is a committee that fundamentally trusts the agencies.

Nevertheless the new report is a step change. There are parts that are downright awful – such as its attempt to smear privacy groups as

being in favour of deaths through terrorism – and some parts that are relatively thorough. On the future job that the ISC should be doing, the committee is silent; perhaps it feels it shouldn't judge its own work, but it's been the most important failure within the system. As the body charged with oversight of GCHQ, it should have spotted the growth in capabilities, especially 'bulk collection', or TEMPORA as it's known to those of us who read the papers. Either the committee didn't spot the change, or it didn't think it was important enough to tell Parliament. Either way, it's the ISC that should have insisted on a democratic mandate for these powers to hold vast amounts of personal information, and sift and share it.

As such, it isn't surprising that the ISC gives the agencies and their newfound capabilities a clean bill of health. Alongside judgements from the highly limited Investigatory Powers Tribunal, which have found no more than procedural wrongdoing, this gives the media and MPs the impression that there's little to worry about.

British institutions are, in my view, tremendously well trained in assessing the minimum concessions needed to contain a problem. In surveillance, there has been legal



designed to minimise risk while preserving our essential democratic life. It would be perfectly possible to reduce free movement, association and privacy to a point where terrorism was virtually impossible, but we would then be living in a police state.

The ISC's job should be to assess the actual risks, costs and benefits that the agencies are assessing in their decisions, which simply isn't discussed in the report. If the ISC acquired the expertise to understand the risk models, it would be in a much better position to understand the claims made for data analysis. A simple objection to putting the vast majority of the UK's cash into data gathering should be that human intelligence is failing to keep on top of current threats.

More broadly speaking, gathering and analysing vast amounts of data implicates us all, and this fact alone requires a real debate, prior to building the tools. The same is true for other, difficult questions. The tools we discussed last issue, that enable direct exploitation of computer equipment, rely on the general insecurity of computers. Sometimes GCHQ may be contributing to this insecurity. How justifiable would that be? And who should oversee these decisions? The ISC says there's no oversight, and GCHQ should tell ministers if a problem may arise.

There are other missing discussions. The UK's data sharing arrangements include giving the NSA access to raw data streams; how is that managed?

Who in the UK might be looked at? What are the strategic implications of integrating GCHQ and the NSA at a technological level? How will the UK manage the military and offensive capabilities that GCHQ has developed on the back of invasive techniques? If you can control a computer, you can disrupt as well as conduct surveillance. The overall impression is that the ISC hasn't yet worked out the job of surveillance oversight in the digital age. **GPC**

recognition of our agencies since 1989, but surveillance laws were properly codified for the first time in 2001. The pace of change has been glacial. The ISC report offers us the next logical step: clearer, tidier laws, and improved transparency from the agencies. On the substantive issues, however, it doesn't even call for a public debate about the nature of its powers.

There's a vast conceptual gap between the ISC and human rights campaigners about what the ISC calls 'bulk collection'. The ISC claims that bulk collection is restrained to what's necessary because, for instance, only some of the Internet is harvested by GCHQ.

The information within it is only seen after careful 'selection' criteria are applied. Targets are distinguished between UK and foreign communications. An email from one UK resident to another would be domestic, but a Facebook post would be foreign.

The ISC acknowledges that the underlying data will contain all kinds of information, including privileged communications. The case for its methods being justified relies

on two arguments: firstly, that what is seen (or kept for the long term) relies on 'selectors' such as email addresses being applied.

The second argument is that data mining and analysis tools are able to use pattern analysis to find new suspects and intelligence.

It's a beguiling argument, and it's hard to argue that agencies should give up powers they 'know' work against dangerous criminals. That's why Rifkind and Blears asked human rights groups if they would be willing to see terrorists kill people, as the price for individual privacy. Perhaps unwisely, some said that yes, in a free society you have to accept that dangers will occur, and that rights such as privacy shouldn't simply be abandoned. Or, as Benjamin Franklin said, 'those who would give up essential liberty, to purchase a little temporary safety, deserve neither liberty nor safety'.

The ISC then got itself a Times front page headline condemning irresponsible human rights groups, yet it's the ISC itself which must assess whether different security policies are endangering lives; and everyone accepts that all policies are

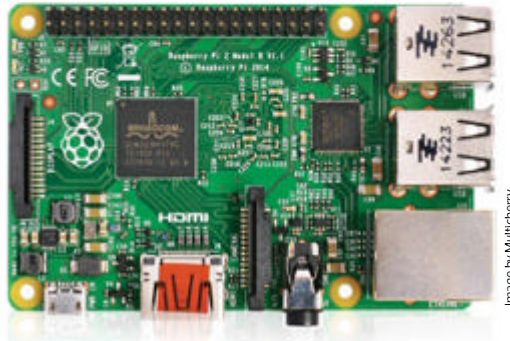


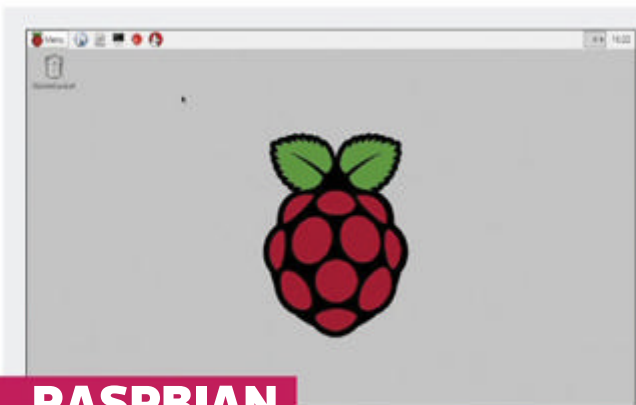
Image by Multicherry

Raspberry Pi 2

It's a whole computer on a single PCB that costs just £30, and it will even run Windows 10 in the future. Gareth Halfacree investigates what you can do with the Raspberry Pi 2 (review on p94), from the operating systems it can run to how to turn it into a media streamer or file server, and finishing off with all sorts of tips and tricks



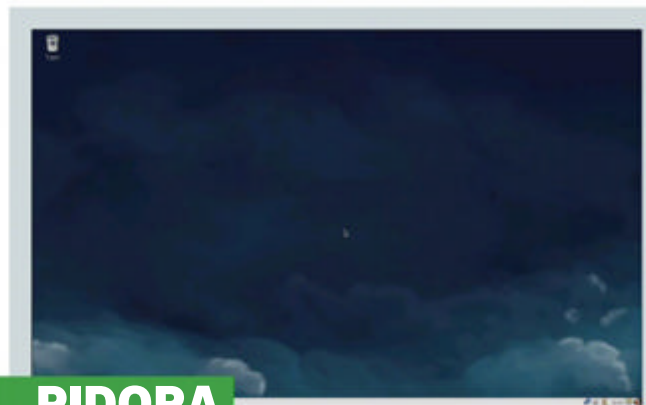
SOFTWARE RUNDOWN



RASPBIAN

The obvious choice for a general-purpose operating system, Raspbian was the first OS to receive support for the Raspberry Pi 2, and in a very clever manner. Rather than branching into two builds, Raspbian detects whether it's running on the original ARMv6 BCM2835 or new ARMv7 BCM2836 and loads an appropriate kernel; everything in user-space, meanwhile, uses ARMv6 code.

Although that means Raspbian can't take full advantage of the new features of the BCM2836, the performance is still convincingly higher, and you can take an up-to-date Raspbian micro-SD card from any original Raspberry Pi and insert it into a Raspberry Pi 2 without difficulty, and vice versa. Coupled with the recently released hardware-accelerated browser, Raspbian on a Raspberry Pi 2 makes for a surprisingly usable casual desktop replacement for lightweight office work.



PIDORA

The Pi-compatible spin of Red Hat-based Linux distribution Fedora, Pidora was lagging behind the Debian-based Raspbian for compatibility; at the time of writing, the official download from the Raspberry Pi Foundation was marked as incompatible with the Raspberry Pi 2. For anyone who can't live without their rouge chapeau fix, an alternative exists in the form of a community-built spin of Fedora 21, dubbed Fidora, and it's available in the form of SD card images with a minimal install, and Xfce, KDE or LXDE desktop environments as required.

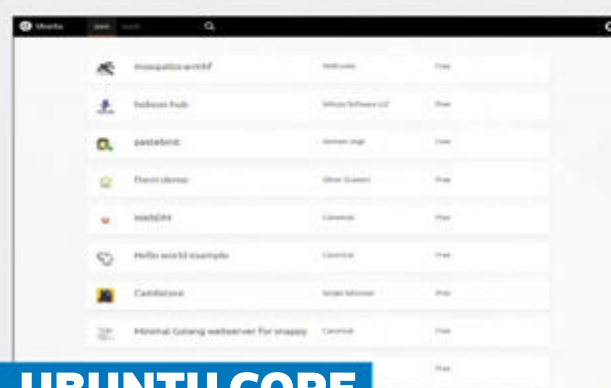
As this feature went to press, it was unclear whether Pidora's development would continue or whether it will find itself replaced on the official download pages and within the NOOBS installer by Fidora. In the meantime, Fidora can be downloaded from www.digitaldreamtime.co.uk/images/Fidora for manual installation on an 8GB or larger micro-SD card.



RISC OS

One for the nostalgists, RISC OS is the operating system originally developed for the Acorn Archimedes and RiscPC family of ARM-based computers. Given the Raspberry Pi's ARM-based processor, it's a natural fit for the device and includes many of the features you'd expect from a modern operating system, while being immediately familiar to anyone who grew up with Acorn products.

Since RISC OS RC14, the operating system has natively supported both the BCM2835 and BCM2836 processors and – much like Raspbian – can be used on either device with no modifications required. For anyone who requires ultimate responsiveness, RISC OS is a great choice, but don't expect to have the same expanse of third-party software that's available with the more mainstream Raspbian or other Linux- or BSD-based systems.

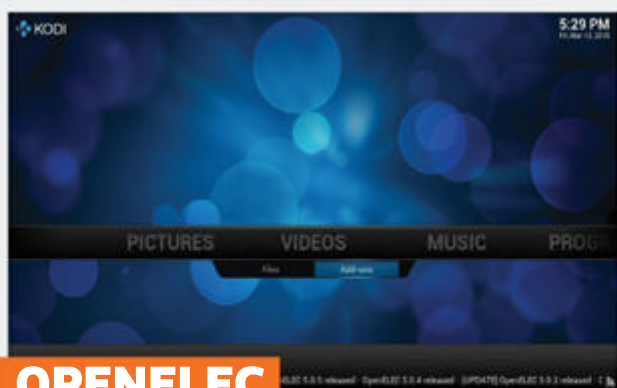


UBUNTU CORE

While Ubuntu had initially been a planned operating system for the original Raspberry Pi boards, Canonical's decision to drop support for the ARMv6 microarchitecture meant it's never been compatible – until now. With the ARMv7 BCM2836, it's possible to run Ubuntu on the Raspberry Pi 2 – but not the original models.

However, you'll be disappointed if you're expecting a desktop-class experience. The version of Ubuntu released for the Raspberry Pi is a new spin dubbed Ubuntu Core, and developed specifically for embedded platforms.

Ubuntu Core is a command-line slimline distribution that dispenses with Ubuntu's usual apt package manager in favour of a new package format dubbed Snappy. While it offers plenty of potential for developers, there isn't much here for the average user.

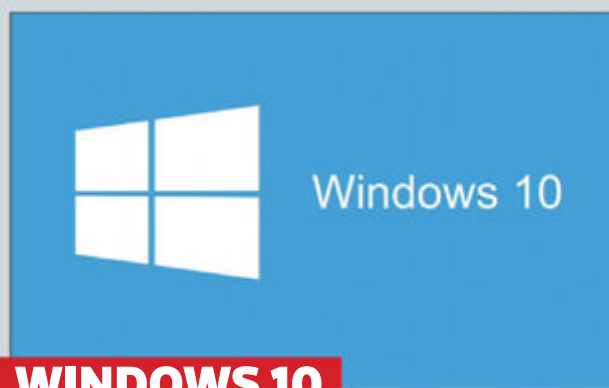


OPENELEC

The most popular media-centric Linux distribution for the original Raspberry Pi boards, OpenELEC now supports the new Raspberry Pi 2, meaning it can finally address the poor performance of the Kodi user interface by throwing more compute power at it.

While the version available on the Raspberry Pi downloads page was, at the time of writing, only available for the original model, a manually downloaded image or one installed through NOOBS (new out-of-the-box software – see www.raspberrypi.org/help/noobs-setup) offers compatibility with the new Raspberry Pi 2.

Be careful, though, as the project has split into two images – one for the BCM2835 and the other for the new BCM2836. For more information on how to install and use OpenELEC, turn to p88.



WINDOWS 10

The announcement that the Raspberry Pi Foundation had partnered with Microsoft to bring support for Windows 10 to the Raspberry Pi 2 was a shock, especially given the company's recent decision to cease development of the Windows for ARM branch it used on the Surface tablet family.

Anyone hoping that the promised free download will enable a cheap desktop replacement are going to be disappointed, however: although Microsoft has yet to release full details, the company has indicated that Windows 10 for the Raspberry Pi 2 will be an embedded-centric build aimed at developers. The company has previously released a similar variant of Windows 8.1 for Intel's Galileo development board, and it isn't a system you'll be using for day-to-day computing. Windows 10 will also, like Ubuntu Core, be exclusive to the BCM2836; original Raspberry Pi owners need not apply.



TUTORIALS

Media streamer

One of the most common tasks for a housebound Raspberry Pi is to act as a media streamer, and that's a job that the new Raspberry Pi 2, with its more powerful quad-core processor, can do with aplomb. Using the latest OpenELEC build, there's no hint of the lag that plagued the user interface on the original Pi, and installing it is a breeze.

1 Download OpenELEC

Head to <http://openelec.tv/get-openelec> and scroll down to the Raspberry Pi Builds section. Note that there are six images in total: four ARM11 builds and two ARMv7 builds. For the original Raspberry Pi, you would need an ARM11 version; for the new Raspberry Pi 2, download the OpenELEC disk image – the last link in the list – and extract it to a convenient location on your main machine. If you're installing via NOOBS, rather than using a manual download, make sure you've chosen the OpenELEC build labelled 'Pi2' and skip the next step.

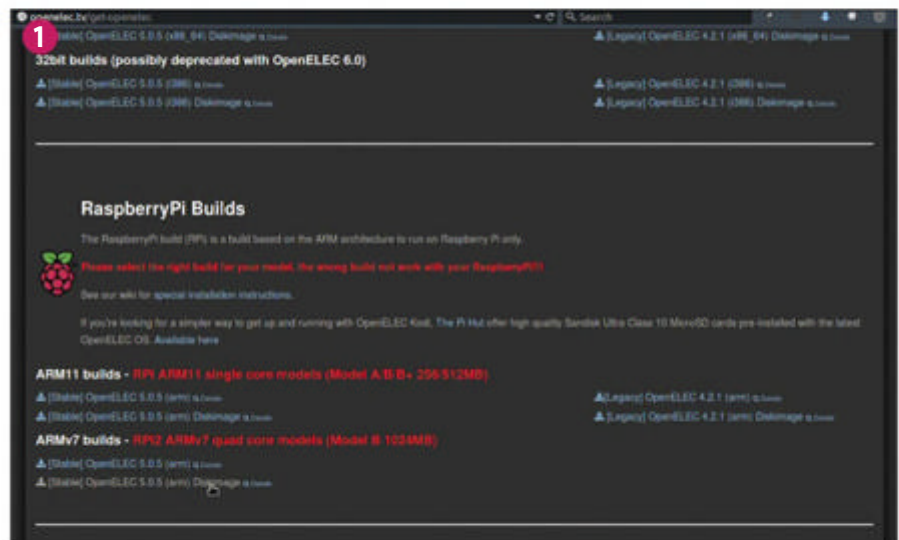
2 Write image to micro-SD card

The image file needs to be written to a micro-SD card, a process that will wipe any existing content from the card. If you're using Windows, connect your card to your PC via a reader, then download Win32 Image Writer from <http://j.mp/win32iw> and use it to write the uncompressed image file to your SD card. Users of Linux, OS X and other Posix-style operating systems can instead use the dd command line to write the image with the following command, where XXX is the device ID of your SD card:

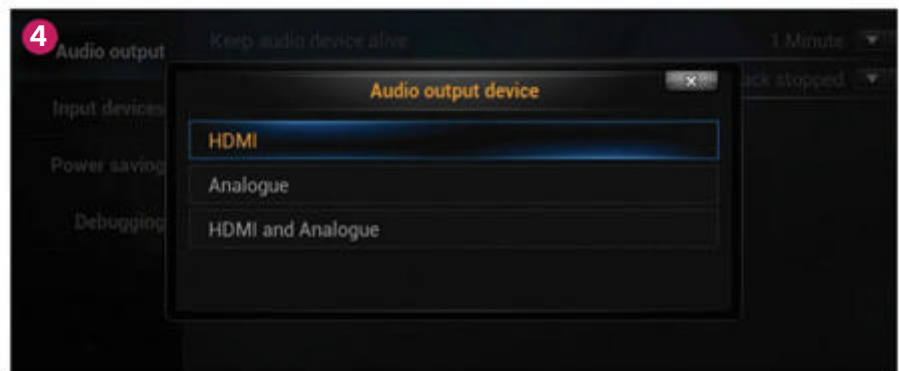
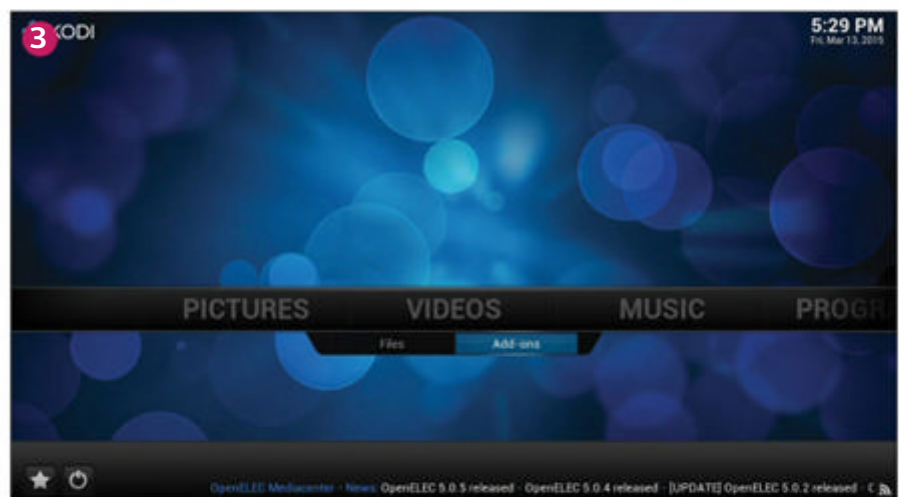
```
dd if=OpenELEC-RPi2.arm-5.0.6.img of=/dev/XXX
```

3 Initial boot

Slide the micro-SD card into the slot on the underside of the Raspberry Pi and connect your peripherals. At the minimum, you'll need a display connected to either the HDMI port or the composite video output, and a network cable. You'll also need a way to control the Pi – a wireless keyboard with a built-in touchpad is a sound investment here, and its receiver dongle should be connected to a USB port. If you have any media on external hard drives, you can connect them as well. Make sure your display is switched on and the correct input is selected, then connect



```
blacklaw@trioptimum:~/Downloads$ dd if=OpenELEC-RPi2.arm-5.0.6.img of=/dev/sdc
```



the Pi to power. The initial boot takes a while, so be patient.

4 Configure audio

For direct connection to a TV via the Pi's HDMI port, the defaults in OpenELEC should

suffice; the video output will be set to the highest resolution the display reports in its EDID, and the audio will be set to digital output over HDMI. If you're looking to use the analogue audio from the 3.5mm jack, you'll need to scroll to Settings and choose System.

Scroll down to Audio Output, then choose Audio Output Device. You'll be given the choice of HDMI, Analogue or both simultaneously. Be aware that the analogue audio output from the Raspberry Pi 2 isn't great quality, and using digital audio via HDMI may be preferable.

5 Download add-ons

OpenELEC is capable of connecting to multiple media sources on your network out of the box. Music, image and video sources can be configured to point to DLNA servers – from a NAS box, for example, or a hard drive connected to the Pi's USB port. For more flexibility, community-contributed add-ons can be installed. In the Video menu, choose Add-Ons then select Get More. A list of available add-on streaming sources will then load, from news channels such as Bloomberg



to comedy sites such as Funny Or Die. Choose any add-on, and it will be downloaded and installed automatically. The

Music and Pictures menus have similar add-on lists available; browse through them to tailor OpenELEC to your requirements.

File server

While the strange configuration of its USB and network ports – which share a single USB 2 channel to the system-on-chip (SoC) – may limit the performance of the Raspberry Pi 2 when acting as a file server, its low cost and minuscule power draw mean it's still a good choice for anyone who doesn't need high-speed throughput.

1 Install Raspbian

If you're already running Raspbian, you can skip this step. If not, the easiest way to get Raspbian running on your Raspberry Pi 2 is via NOOBS. Head to www.raspberrypi.org/download and download the latest version. Ensure that your micro-SD card is formatted to FAT32 or VFAT – if it's ExFAT, you'll need to reformat it – and extract the contents of the NOOBS Zip archive onto it.

Insert the micro-SD card into the slot on the underside of the Raspberry Pi 2, then connect the Pi to a display, keyboard and network. The display and keyboard are only needed for installation and configuration; once you've installed Raspbian and set up your file server, they can be disconnected.

Power on the Pi, and select Raspbian to install it. This will take a few minutes, after which you'll be prompted to reboot into Raspbian. Do so, then exit the configuration screen that appears. Now is also a good time to change the default password, by typing the `passwd` command at the console.

2 Update and install Samba

A fresh install of Raspbian isn't going to be running the very latest packages, so run the following command to ensure it's up to date: `sudo apt-get update && sudo apt-get upgrade && sudo rpi-update`

When the updates have finished, reboot with the following command:
`sudo reboot`

Log back in, and type the following command to install Samba:

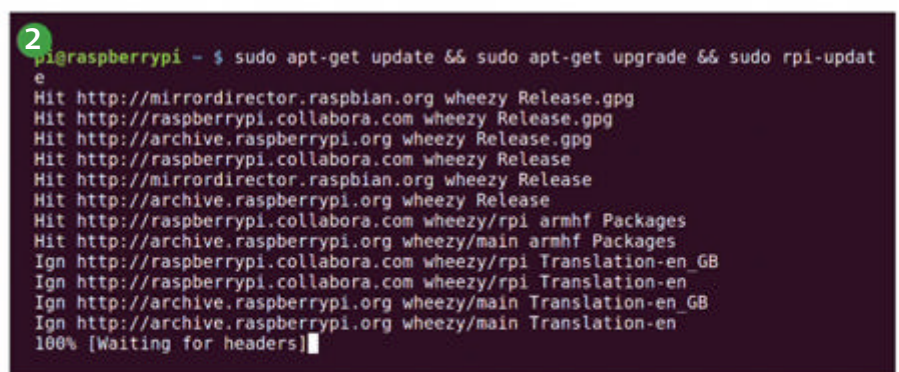
```
sudo apt-get install samba
```

Samba is a networking server system designed to be compatible with the Server Message Blocks (SMB) standard on which Windows networking is based. It allows you to share your files to Windows, Linux, OS X and other hosts, without having to mess around with third-party clients.

3 Configure your storage

You're going to need somewhere to store your files. If that's an external hard drive, the easiest way to get it up and running is to load the GUI with the `startx` command. You can then connect your external hard drive – it will be automatically mounted – and make a note of the location, which will be in the format `/media/partitionname`.

It's fine if the partition name is a string of numbers or hexadecimal digits, which just indicates that the partition was never labelled when it was created.



If you don't have an external hard drive, and you want to use the Pi's micro-SD card for storage, create a new directory with the following command:

```
mkdir ~/FileServer
```

Note that Linux is case-sensitive; if you use a capital F and capital S, as in this example, you'll need to always use the same case when you type the directory name later. In either case, to allow anonymous read-write access from your local network – a serious security concern, so be sure you want to do this – you'll need to change the permissions:

```
sudo chmod 777 path
```

Replace path with either /media/partitionname or ~/FileServer, as appropriate. Without this step, unauthenticated users will be able to read files but not modify or create new ones.

4 Configure Samba

At a terminal – either the console or a terminal window if you've loaded the GUI – type the following command:

```
sudo nano /etc/samba/smb.conf
```

Scroll to the bottom of the file, then add the following lines:

```
[storage]
comment = Raspberry Pi 2 File Server
browseable = yes
path = path
guest ok = yes
read only = no
create mask = 0775
```

Replace path with either the partition location: /media/partitionname or /home/pi/FileServer if using the SD card. Save the file with Ctrl-O, then exit with Ctrl-X. Restart Samba to load the new configuration with the following command:

```
sudo /etc/init.d/samba restart
```

5 Access the file server

To use the Raspberry Pi's new file-serving capabilities, you'll need to know its IP address, which you can find with the following command on the Pi:

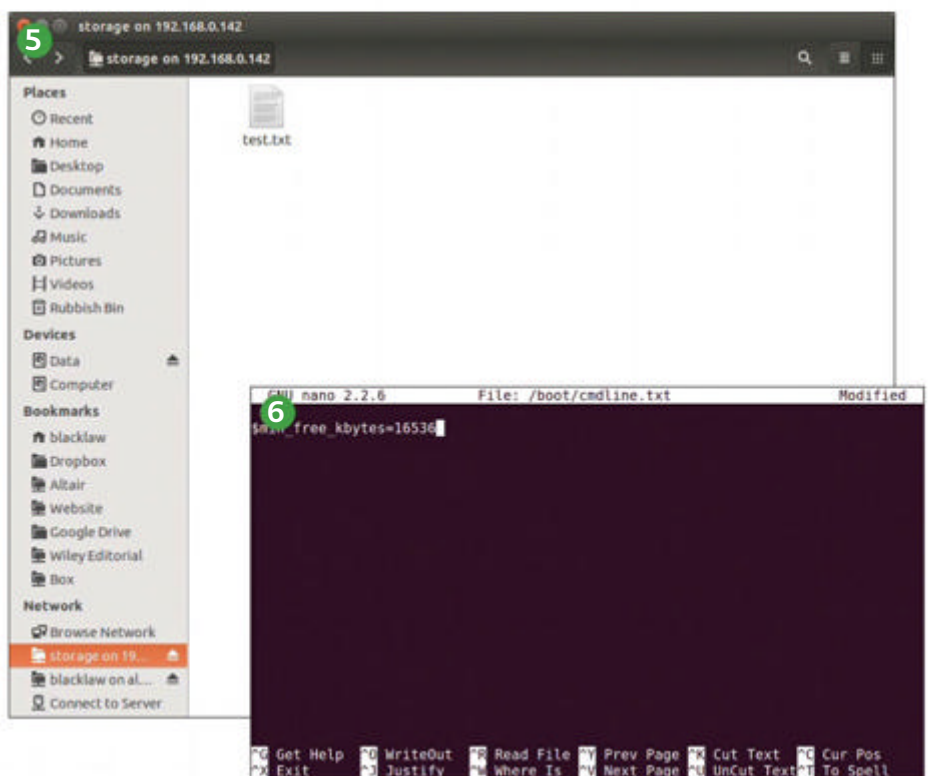
```
ifconfig | grep inet\ addr
```

Taking the first IP, rather than 127.0.0.1 (a loopback address), load Windows Explorer – or your favourite file manager – and attempt to connect to the server. If you're prompted for a username and password, use 'pi' and whatever password you chose in the first step. When the file-browsing window loads, try dragging and dropping some files onto it. These files will be copied across to the Pi, but be warned: the maximum speed you'll get from it is around 10MB/sec, so don't expect ultra-fast file transfers.

```
3 pi@raspberrypi ~ $ mkdir ~/FileServer
pi@raspberrypi ~ $
```

```
4 GNU nano 2.2.6 File: /etc/samba/smb.conf Modified
# /dev/scd0 /cdrom iso9660 defaults,noauto,ro,user 0 0
#
# The CD-ROM gets unmounted automatically after the connection to the
#
# If you don't want to use auto-mounting/unmounting make sure the CD
# is mounted on /cdrom
#
; preexec = /bin/mount /cdrom
; postexec = /bin/umount /cdrom

[storage]
comment = Raspberry Pi 2 File Server
browseable = yes
path = /home/pi/FileServer
guest ok = yes
read only = no
create mask = 0775
```



6 Tweak the kernel

This step is optional, but if you find your Pi has a tendency to crash or reboot itself during heavy network traffic, you may need to work around a couple of bugs in the firmware. At the terminal, run the following command:

```
sudo nano /boot/cmdline.txt
```

At the end of the line, after 'rootwait', add the following two entries ensuring that they're separated by a space and not a new line:

```
smc95xx.turbo_mode=N vm.min_free_kbytes=16536
```

The first setting disables the network chip's 'turbo' mode, which is known to cause instability, while the second entry helps to prevent memory page allocation errors that can otherwise build up.

You can then save with Ctrl-O and exit with Ctrl-X, then reboot the Pi with the following command:

```
sudo reboot
```



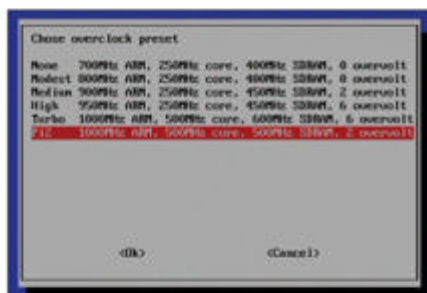

TIPS AND TRICKS

Overclocking

The similarities between the original BCM2835 and the new quad-core BCM2836 extend to their support for overclocking, providing power users with a means to wring a little more power out of their Raspberry Pi at the risk of a shortened lifespan. The safest way to get some extra speed out of your new device, assuming you're running Raspbian, is to use the configuration wizard. At the terminal, type:

```
sudo raspi-config
```

Scroll down to 7 Overclock, hit Enter, read and acknowledge the warning, then choose the bottom option – labelled Pi2 – from the list that appears. Make sure you don't use any of the other options, including None; these settings are designed for the original Raspberry Pi, and could leave your shiny new Pi 2 running slower than stock speed. Exit the tool by tabbing to Finish and confirm you'd like to reboot when asked. For even higher



speeds, you can adjust settings directly within the boot configuration file. Run the following command at the terminal:

```
nano /boot/config.txt
```

Head to the bottom of the file, and use the following to adjust the performance of the processor:

`arm_freq` - Core clock frequency in megahertz

`gpu_freq` - GPU clock frequency in megahertz

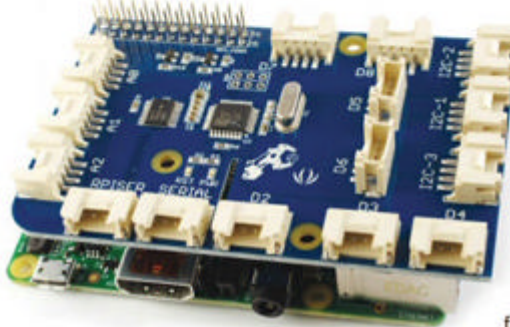
`sdram_freq` - Memory clock frequency in megahertz

`over_voltage` - Increase the SoC's voltage, in steps of 0.025V

Be aware, however, that manually adjusting these settings – in particular the voltage – can render your warranty void.

GPIO expansion

Although the latest Raspberry Pi models have a longer general-purpose input-output (GPIO) header than their predecessors, it still lacks many functions of rival devices – in particular support for



hardware pulse-width modulation (PWM) or analogue inputs. The solution is a GPIO expansion board.

There are plenty of add-ons from which to choose, many of which are tailored to a particular task such as robotics or home automation. A comprehensive list is available at http://elinux.org/RPi_Expansion_Boards

Highlights include: the (pictured) Dexter Industries GrovePi (£25 inc VAT, www.robotshop.com/uk), which adds support for Seeed Studio's Grove sensor modules; the ADC Pi (£23 inc VAT, www.abelectronics.co.uk), an 8-channel analogue-to-digital converter; the PiDuino (£18 inc VAT, <http://skpang.co.uk>), which adds Arduino capabilities; and the Adafruit 16-channel PWM HAT (£16, <http://shop.pimoroni.com>), to provide support for controlling servos or other PWM devices.

Updating the firmware and kernel

You're almost certainly aware that Raspbian needs regular updates to keep it performing in tip-top condition, but you may be running an older kernel and firmware release if you're relying on the traditional method of using this command:

```
sudo apt-get update && sudo apt-get upgrade
```

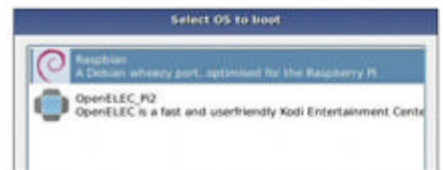
To ensure you have the very latest kernel and modules – providing bug fixes, stability and even performance improvements – you need to use a separate tool bundled with Raspbian. At the terminal, type the following command:

```
sudo rpi-update
```

This command refreshes the firmware, kernel and all the modules from the official GitHub repository, ensuring that your system is bang up to date.

Multi-boot via NOOBS

While its name may suggest that it's designed for newcomers, NOOBS (New Out-Of-Box Software) includes one feature that power users may find very useful indeed: multi-boot support. Download NOOBS from www.raspberrypi.org/downloads, and extract the contents of the Zip to a FAT32-formatted micro-SD card – there's no need



to mess around flashing raw images. Insert the card into the Pi and boot it, then tick the boxes next to as many operating system as you'd like to install.

When installation is complete, the next boot will load a menu asking which of the installed operating systems you want to boot. Future boots will display this menu for ten seconds, after which the most recently booted OS will be automatically selected. When installing your OS, however, be aware that not every choice available in NOOBS is yet compatible with the Raspberry Pi 2.





RIVAL BOARDS

The Raspberry Pi may not have been the first single-board computer on the market, but its success – selling five million units and counting – has led to an explosion in the market never seen before. Here's a look at the most notable competition to the Pi.



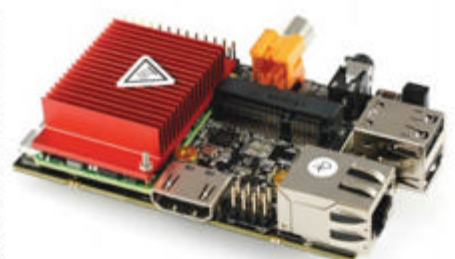
Lemaker Banana Pro / **£37 inc VAT**
SUPPLIER www.aliexpress.com

The follow-up to Lemaker's Banana Pi, as reviewed in Issue 131, the Banana Pro improves on the original design by adopting the new B+ / Raspberry Pi 2 GPIO header and adding integrated 802.11/b/g/n Wi-Fi. Additional features over the Raspberry Pi 2 include on-board SATA, infrared support, Gigabit Ethernet and wider compatibility with various operating systems. Its dual-core AllWinner A20 processor, however, lags behind the Pi 2's BCM2836 in the performance stakes, and there are only two full-sized USB 2 ports – although, unlike the semi-compatible ports of the Pi, they're fully standards-compliant.



Intel MinnowBoard Max /
€215 inc VAT (around £153)
SUPPLIER www.tigal.com

One of several open-hardware projects Intel is throwing at the hobbyist market, the MinnowBoard Max is significantly more expensive than the Raspberry Pi but includes a full-fat dual-core 64-bit x86 Atom processor and 2GB of RAM in its top configuration. As detailed in Issue 136's review, it's a significant improvement over the 32-bit original and boasts some of the best software compatibility of any hobbyist single-board computer. It lacks the community built up around the Raspberry Pi, however, and the add-on Lure boards for it are currently thin on the ground.



SolidRun HummingBoard /
£80 inc VAT
SUPPLIER www.newit.co.uk

Reviewed in Issue 134, the HummingBoard began life as an internal development board. Available in several editions, ranging from a single-core model to the reviewed HummingBoard-i2ex, it uses an uncommon computer-on-module (COM) design. As such, it's theoretically possible for SolidRun to release upgraded modules you can buy at a lower cost to replacing the entire device, although no such modules have appeared yet. A promised quad-core variant is also missing, leaving the top-end model lagging behind the Raspberry Pi 2, despite using the more efficient Freescale i.MX6 SoC.



CubieTech Cubieboard 4 /
£133 inc VAT
SUPPLIER www.newit.co.uk

The Cubieboard 4 might be bulky and pricey, but it's a beast. Based around the AllWinner A80 SoC, it packs four Cortex-A15 1.8GHz and four Cortex-A7 1.2GHz cores in ARM's big.LITTLE layout, but with the ability to run all eight cores simultaneously, giving highly threaded workloads a great speed boost. The 2GB of RAM is also generous, but the PowerVR G6230 GPU means hardware graphics acceleration is unavailable outside Android – a major blow for anyone hoping to run a more flexible operating system.



Hardkernel Odroid C1 / **£35 inc VAT**
SUPPLIER www.lilliputdirect.com

As soon as the Raspberry Pi 2 was announced, Hardkernel was quick to position the C1 as a more powerful alternative board. Based on an Amlogic SoC, the Odroid C1 includes four 1.5GHz Cortex-A5 cores, a Mali-450 MP2 GPU and 1GB of DDR3 memory, along with Gigabit Ethernet and a Raspberry Pi +/2 compatible 40-pin GPIO header.

Support for Android and Ubuntu 14.04 is included as standard, but the board again lacks the excellent community enjoyed by the Raspberry Pi.



Imagination Technology
 Creator CI20 / **£50 inc VAT**
SUPPLIER <http://store.imgtec.com/uk>

The Creator CI20 uses the MIPS instruction set rather than the more common x86 or ARMISAs. The CI20 has enjoyed an upgrade since it was reviewed in Issue 139, with double the flash storage at 8GB and an eye-catching purple PCB. Its dual-core 1.2GHz CPU is also more efficient than its ARM rivals, but can't beat the quad-core BCM2836 for multi-threaded speed. Its PowerVR SGX540 also lacks acceleration support outside Android, although Imagination has promised to address this issue in the future. **GPG**



GARETH HALFACREE'S

Hobby tech

The latest tips, tricks and news in the world of computer hobbyism, from Raspberry Pi, Arduino and Android to retro computing

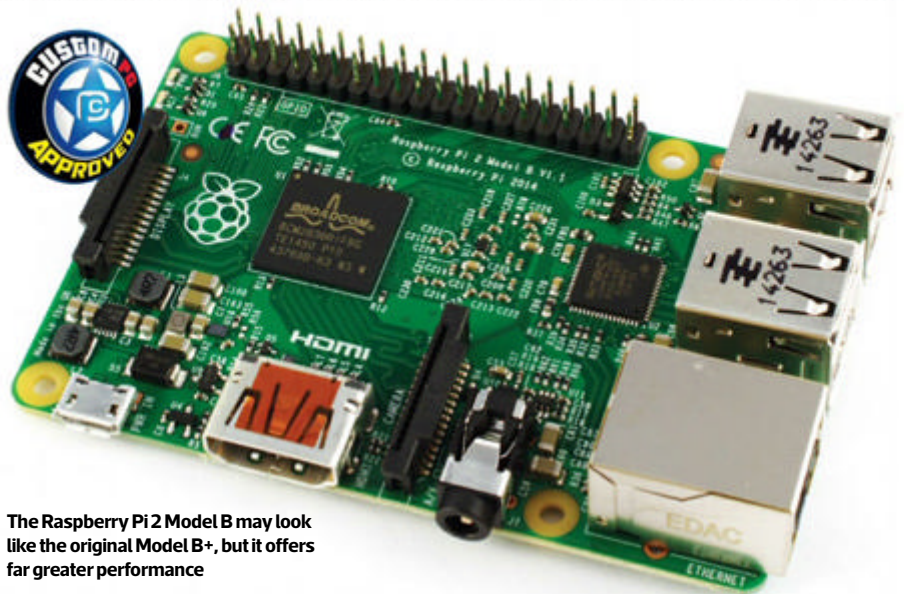
REVIEW

Raspberry Pi 2

In the three years since launch, the Raspberry Pi has retained the heart of its design: whichever model of Raspberry Pi you picked up, from the original Model B through to the new Plus variants and the compact SODIMM-form-factor Compute Module, you got the Broadcom BCM2835 system-on-chip (SoC) processor as the brains of the beast.

For many people, that was a problem. With a single ARMv6 processing core running at 700MHz, the BCM2835's general-purpose performance is poor. Sure, it has a surprisingly beefy GPU, as the SoC's original target market was multimedia set-top boxes, but that doesn't make up for a CPU that's slow enough to make certain applications unusable. Coupled with poor software compatibility, with ARMv6 being retired in favour of the more efficient ARMv7 microarchitecture before the original Raspberry Pi ever shipped, the original Pi involved some major trade-offs to hit that magic sub-£30 price point.

Enter the Raspberry Pi 2. Launched just ahead of the Foundation's third birthday, this single-board computer is externally near identical to the Model B+. It has an extended 40-pin GPIO header, an Ethernet port, four USB ports, an analogue AV port and an HDMI



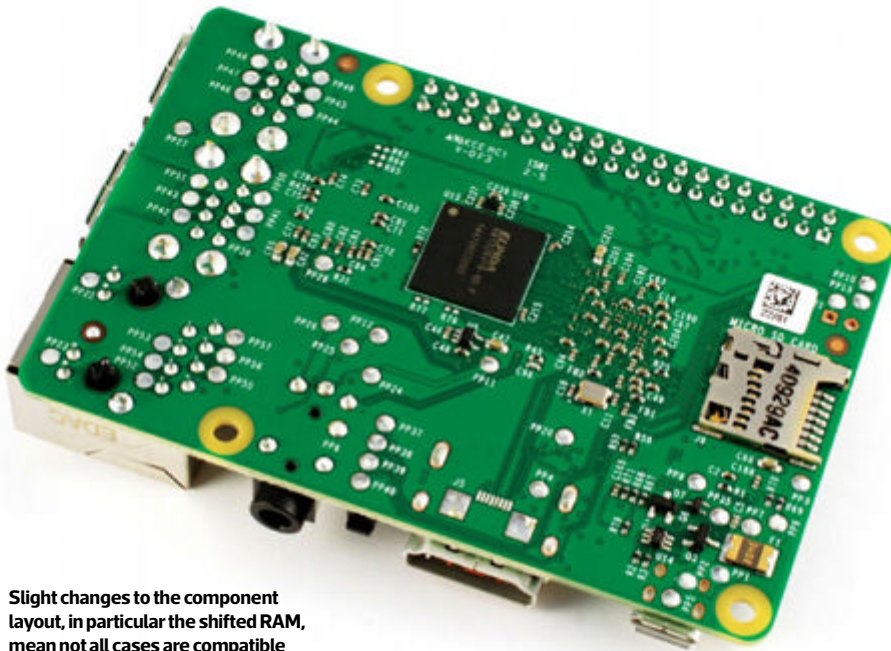
The Raspberry Pi 2 Model B may look like the original Model B+, but it offers far greater performance

connector, along with CSI and DSI connectors for cameras and display panels. The first hint of a difference, aside from the slightly smaller logo, is the main chip in the middle, which now carries the Broadcom logo.

This chip is the BCM2836, a direct successor designed as a near drop-in replacement for the aging BCM2835 and created specifically for the Raspberry Pi. The old package-on-package format that saw the

SoC sandwiched between the board and a 512MB DRAM module has gone, with the memory now located on the underside, and the new SoC taking pride of place.

As well it should, really: the BCM2836 includes a quad-core 900MHz processor that supports the ARMv7 instruction set architecture. While the clock speed is only a small increase over its predecessor, the performance gains aren't inconsequential: the



Slight changes to the component layout, in particular the shifted RAM, mean not all cases are compatible

Foundation says you can expect a sixfold increase for most common workloads.

Coupled with a doubling of memory to 1GB, that's cause for celebration – but how true is the claim? Perhaps surprisingly, it bears scrutiny: running SysBench on the Raspberry Pi 2 gave a total execution time of 297 seconds compared to 501 seconds for the Model B+ (dropping to 389 seconds when overclocked to the same 900MHz clock-speed).

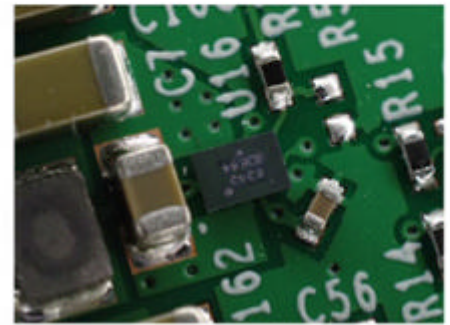
Granted, that's hardly six times faster, but running SysBench across four threads dropped the execution time to just 74 seconds – just shy of seven times faster than the stock Model B+. The same performance difference can be seen in real-world workloads: compressing a file with the multi-threaded pigz compression tool took 80.8 seconds on the Model B+, 69.6 seconds on an overclocked Model B+ and just 11.5 seconds on the Raspberry Pi 2.

The extra performance comes at a cost, of course, and that's power draw: a Model B+

The BCM2836 includes a quad-core 900MHz processor that supports ARMv7

draws 0.65W when idle and 0.85W during CPU load; the Raspberry Pi 2, by contrast, matches the idle draw but hits 1.6W under load. So for battery-based projects, there's a drawback – but given that the original single-core Raspberry Pi Model B drew 1.55W for a fraction of the performance, it's a relatively minor point.

Other areas of the Raspberry Pi have, sadly, been neglected in the hardware refresh, probably in the hope of minimising compatibility issues. The 10/100Mb/sec Ethernet port still goes through a single USB channel to the SoC, killing performance when coupled with USB storage, and there's no



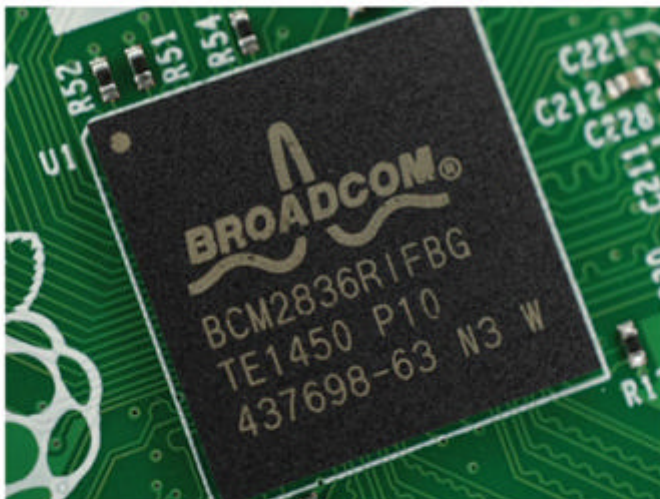
One component, marked U16, causes the Pi 2 to crash when exposed to xenon flashes

difference in network throughput compared with previous models either.

Compatibility has been a thorny issue too. The shift to ARMv7 means improved compatibility with new operating systems, including an extremely limited version of Ubuntu dubbed Snappy Core that's unsuitable for desktop use, and the impending launch of an embedded version of Windows 10 that's similar to the OS used on Intel's Galileo platform. While Raspbian required only a minor update – a new kernel image – to boot on the Pi 2, other common Pi packages weren't so lucky. It wasn't until a week after launch that RPi.GPIO, the Python GPIO library, was modified to work with the new hardware, and at the time of writing, Adafruit's popular PiTFT family of displays was still incompatible.

Assuming that's not a deal killer, though, there's a final piece to the puzzle that makes the Raspberry Pi 2 the obvious choice for future projects: it's available for roughly the same price as the old Raspberry Pi 2 Model B+. For more compact projects, a BCM2836-based Compute Module is planned for release later this year, but nothing has been formally announced about a Raspberry Pi 2 Model A.

The Raspberry Pi 2 Model B is available for £30 inc VAT from <http://cpc.farnell.com>



The new Broadcom BCM2836 SoC offers four 900MHz ARMv7 cores for vastly more compute power



The RAM is now located on the underside of the board, instead of capping a package-on-package sandwich with the SoC



INTERVIEW

Swanky Paint

It's no secret that I have a lot of love for the Commodore Amiga, but while I might wax nostalgic about the games, audio and excellent operating system, there's another main memory from the Amiga years: Deluxe Paint.

DPaint, as it was more commonly known, was first launched in 1985 for the Amiga 1000 and published by Electronic Arts after Dan Silva realised his self-written Prism graphics utility had commercial value. Offering bitmap graphics editing, it rapidly shifted from an exciting new launch to the must-have tool for the Amiga, and when it jumped formats to MS-DOS, it became a standard tool for producing 2D graphics in games.

Discontinued in 1994, DPaint still has an army of fans – including Wetgenes, a two-person games company looking to bring DPaint to a new audience with a spiritual successor dubbed Swanky Paint. 'DPaint was simply the best paint package there was; the Photoshop of the past, if you will,' explains Kriss Blank, who founded Wetgenes with wife shi in 2003. 'Years later, it still represented a way of doing things that kept me coming back for low-res pixel work. I don't think you can improve on the brutal simplicity of the original DPaint.'

Swanky Paint takes the core concepts of DPaint, right down to the shortcut keys, and



Husband and wife team Kriss and shi Blank created Swanky Paint as a tool for pixel artists

rebuilds it for the modern age, but still with a focus on low-resolution pixel art. That's now a conscious style choice, rather than the technical limitation it was in the Amiga days – a choice that's driven largely by independent game developers.

'Because more people are creating [games], pixel art seems an obvious style

choice for your sprites: it's fast and relatively easy to create graphics that look much better than your average stick figures,' explains shi. 'Everyone who has had a go seems to like it, even those that are used to the Photoshop method, since it's a totally different approach to pixels for them. People who do remember DPaint love it.'

Swanky Paint was written to be cross-platform. 'The main impetus for creating Swanky Paint was finally moving away

from Windows as a development environment and losing a few Windows-only tools in the process,' Kriss says. 'All I require to build [Swanky Paint] is a C compiler and OpenGL ES 2-compatible hardware. Luckily, this covers most modern machines, Android devices, browser-based systems with NaCl+WebGL and even the Raspberry Pi, all of which are build targets along with Windows, Linux and OS X.'

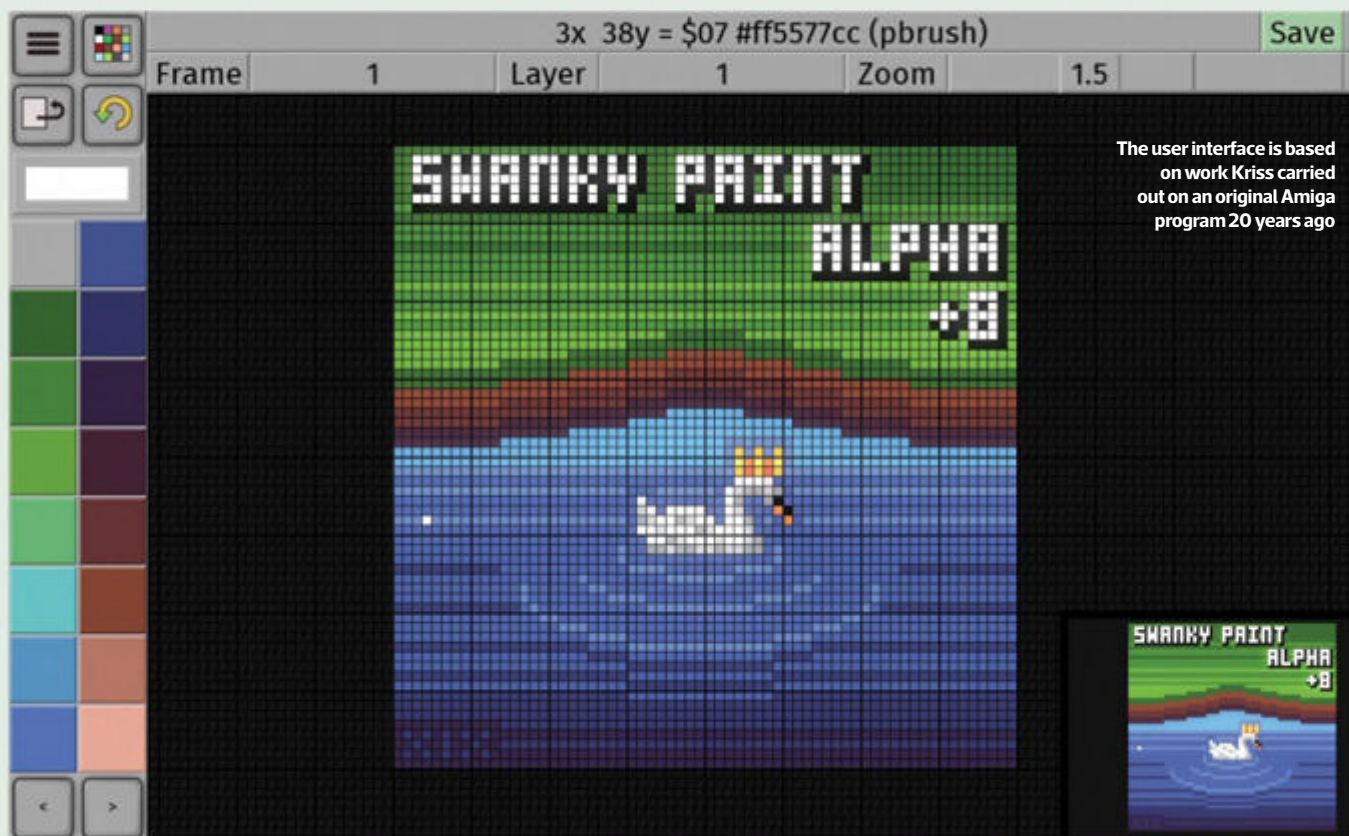
'The GUI design is based on a project I wrote 20 years ago for the Amiga when I was working at Almathera on Photogenics. I ended up hacking together something that was similar to MUI [Magic User Interface, a popular Amiga GUI utility] – it was my first attempt at building a real GUI system.'

The browser-based variant of Swanky Paint, which runs within Google Chrome, offers up some interesting possibilities. 'Swanky Art, our pixel art community, has seen regular creations made using the browser-based version of the software,' explains shi, 'or at least a couple of really hardcore users who have gone on to make GIFs and YouTube videos about it! The browser-based Swanky Paint has a limited version of the full capabilities. You'll still need to download the full version that works on your desktop, but it's multi-platform so that's okay.'

Powered by an open-source Lua+C engine created by Wetgenes to power its games,



Inspired by the Amiga classic Deluxe Paint, Swanky Paint has a low-res aesthetic



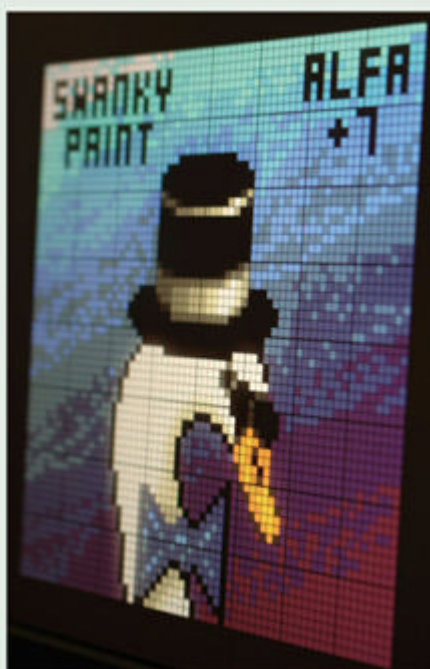
The user interface is based on work Kriss carried out on an original Amiga program 20 years ago

Deluxe Paint was simply the best paint package there was; the Photoshop of the past, if you will

Kriss says that 'most of the actual pixel pushing code is inherited from old game projects where I needed tools to process bitmaps into machine-friendly data for various console games, so although there was work to do, it all involved pre-solved problems.'

Swanky Paint isn't likely to be Wetgenes' last Amiga-inspired project either. 'I'm a fan of Stuart Ferguson's early Amiga 3D software, generically called Modeler 3D and which later became Lightwave Modeler,' reveals Kriss, who received his first Amiga – the classic Amiga 500 – as a gift from his father while still at school.

'I'm planning on creating a similar package to the early Lightwave Modeler, which focuses on very low-poly modelling and integrates well into Blender,' says Kriss. 'There are so many complementary ways to create 3D geometry that no single behemoth application can hope to cover them all, so I feel

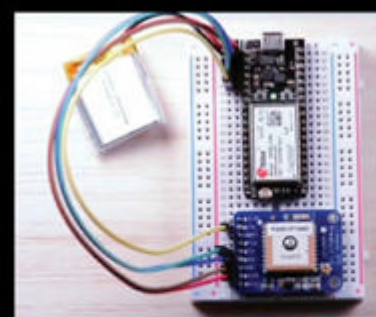


Swanky Paint is entirely cross-platform, running on a variety of platforms – including the Raspberry Pi, as pictured

this is another space where a strange little focused art package, which just tries to do one job well, can fit in with the other tools.'

Swanky Paint can be found on Steam Greenlight or purchased directly from Wetgenes at <http://dime.lo4d.net>, while the Web version can be accessed using the Chrome browser at <http://paint.lo4d.net>

NEWS IN BRIEF



Spark launches Electron

Spark IO, creator of clever Wi-Fi-enabled microcontroller Spark Core, has hit Kickstarter with its latest creation: a new microcontroller that includes 2G or 3G mobile connections. Designed for projects where a Wi-Fi connection can't be guaranteed, the Spark Electron includes a SIM card that offers a global connection priced at \$2.99 a month for 1MB of data – the equivalent of around 20,000 messages to and from the device. The 2G Electron is priced at \$49, while the 3G variant costs \$59. The project has already surpassed its funding goal.

REVIEW

Intel Edison

Originally, the Edison was intended to use the SD form factor and be powered by Intel's shiny new Pentium-class Quark processor. Feedback from users of the Quark-based Galileo development board, however, suggested this idea wasn't going to fly thanks to extremely limited performance. Intel's answer was a swift redesign into a module format, and to combine a 100MHz Quark with a 500MHz dual-core Atom.

The Edison is still impressively tiny, especially when you look at the feature list: as well as the dual-core CPU and low-power co-processor, the 35.5 x 25mm package includes 1GB of LPDDR3 RAM, 4GB of eMMC storage, and 802.11a/b/g/n dual-band Wi-Fi, plus Bluetooth 4 and 2.1EDR. Its 40-pin Hirose high-density connector at the rear also carries 14 GPIO channels (four of which support pulse-width modulation), two UARTs to an SD card channel, I²C, I²S, SPI and even USB.

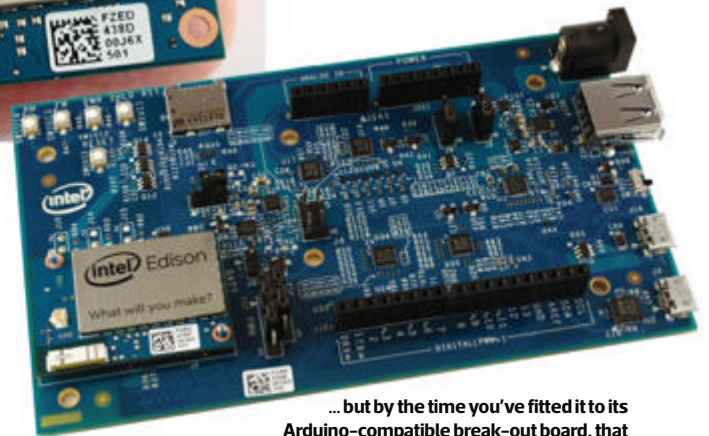
You might wonder how a hobbyist gains access to these wonders, and you'd be right to do so. The official answer from Intel is by using a motherboard into which the Edison bolts; it boasts an Arduino pin-out for GPIO and power, along with USB and micro-SD ports. Using this board, you can turn the Edison into a ridiculously overengineered Arduino Uno, complete with embedded Linux OS and wireless network connection – it isn't 100 per cent compatible with the Uno, but it's good enough for most cases. Doing so, though, negates the size and weight benefits



There's no denying that the Intel Edison, seen here resting on my fingers, is small ...

of the Edison: the Arduino motherboard is nearly as large as three Arduino Uno boards.

A better option, although I haven't been able to test it at the time of writing, comes from US-based hobbyist electronics specialist SparkFun. The SparkFun Blocks for Intel Edison are significantly smaller than the official motherboard, and each one is designed to break out a particular feature: there are Blocks to add analogue to digital conversion, USB ports, motor control, pulse-width modulation, GPIO and even one Block featuring a built-in rechargeable lithium-polymer battery. Each Block has a Hirose connector on each side, enabling them to form a stack that combined whatever features you desire with the Edison as the cherry on top.



... but by the time you've fitted it to its Arduino-compatible break-out board, that size advantage is lost

The fact the SparkFun Blocks had to exist at all, however, shows that Intel has perhaps missed the mark. The Galileo may have been a poor performer, but its form factor was at least well suited to hobbyists; the Edison is only immediately usable with either the oversized breakout board, making it a more powerful Galileo, or with third-party add-ons.

For industry, the Edison offers more possibilities. People who can spend the time designing circuits with tiny high-density connectors will find the Edison more tempting than the relatively feature-light Raspberry Pi Compute Module, and with the added bonus of using the familiar x86 instruction set architecture.

For educational use, combined with the SparkFun Blocks, there's certainly an argument for the Edison. For hobbyist use, though, a Galileo is a better option, as is just forgetting about x86 compatibility and using a proper Arduino board at a fraction of the cost.

The Intel Edison is available for £47.94 inc VAT as a bare module (useless to hobbyists) or £81.54 inc VAT bundled with the Arduino motherboard as reviewed; a cheaper breakout board bundle costs £57.54 inc VAT, all from <http://uk.rs-online.com> **GPC**

NEWS IN BRIEF

Arduino splits, sues self

The Arduino project has attracted some negative attention of late thanks to a split between Gianluca Martino and his co-founders of Arduino LLC. Martino's spin-off company, Smart Projects Srl, produces the official Arduino boards, but has now renamed itself Arduino Srl, which hasn't impressed Martino's fellow founders, who run the separate company Arduino LLC. Arduino LLC and Arduino Srl are now involved in a legal tussle over the Arduino trademark, with the original LLC looking to license manufacturing to other companies, and the Srl seeking to prevent that from happening.



Gareth Halfacree is the news reporter at www.bit-tech.net, and a keen computer hobbyist who likes to tinker with technology. [@ghalfacree](https://twitter.com/ghalfacree)

WIN! A Fuze T2 SE-R Raspberry Pi 2 kit

WORTH
£230
INC VAT

We've teamed up with the very generous folks at Fuze to offer you the chance to win a T2 SE-R Raspberry Pi 2 kit, complete with its BBC Micro colour scheme. The Fuze T2 SE-R is a special edition version of the Fuze, which pays tribute to the home computers from the 1980s when 'bedroom coding' really began.

Fire up Fuze BASIC and the nostalgia comes flooding back, except now, rather than the low processor speed, severely restricted RAM, eight or so colours, low resolution and limited sound systems of the time, the Fuze powered by Raspberry Pi runs at 1GHz and has a 1GB of RAM, millions of colours and incredible sound, not to mention loads of I/O features, including analogue connections.

The Fuze powered by Raspberry Pi 2 provides an ideal, safe and secure Raspberry Pi workstation, retaining all connections via the easily accessible back panel. For added safety, the Fuze also protects the encased Pi from electrical damage via the extended but protected GPIO.

The package includes the following:

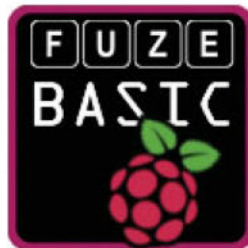
- Raspberry Pi 2
- Fuze case (type II)
- UK keyboard
- Fuze I/O board with analogue connections
- USB hub and power supply
- 8GB micro-SD card pre-loaded with OS and Fuze BASIC
- Solder-less breadboard
- Mouse and mat
- Electronic component kit
- Fuze BASIC Programmer's Reference Guide (hard copy)

QUESTION: Which retro home computer manufacturer originally developed the ARM CPU architecture?

A. Acorn **B.** Commodore **C.** Sinclair



FUZE
Teaching kids to code



Email your answer to competition@custompcmag.org.uk, with 'Fuze Competition 141' in the Subject line.
Closing date 22 May, 2015. See www.dennis.co.uk/comp/terms for the full competition rules.



ANTONY LEATHER'S

Customised PC

Case mods, tools, techniques, water-cooling gear and everything to do with PC modding

Mini-ITX cases – how big is too big?

The size of mini-ITX cases has been the subject of quite a bit of controversy recently, with a couple of new additions following the CES trade show in Las Vegas. The problem? They're big. Very big. Too big for some people. I'll admit that I find myself not quite as loathing of Thermaltake's Core X1 or Phanteks' Enthoo Evolve ITX. Whatever case I use for my main rig, it's going to be completely water-cooled and, as such, despite my love of the mini-ITX form factor, I usually end up with a fairly large case.

Phanteks' Enthoo Evolve ITX isn't quite on the humongous scale, although it's still much larger than BitFenix's already sizable Prodigy. Perhaps more interestingly, Phanteks has applied its usual finesse and created a fantastic-looking case for both air and water-cooled systems. Thermaltake's Core X1, on the other hand, is mind-bogglingly huge. It measures a massive 471mm deep and 426mm high – bigger than many micro-ATX cases.

I'll admit that even I was initially perplexed as to why Thermaltake made such a huge case for this form factor, especially as only some minor alterations would be needed to allow micro-ATX or even a full-sized motherboard to fit inside. However,



Having had some hands on time with Thermaltake's Core X1, I realised how much easier it made building a water-cooled mini-ITX PC

I then remembered just how tricky it can be to install a water-cooling system in cases even as large as the Prodigy or Corsair's Obsidian 250D. I've built several such systems using both cases, and there's only just enough room. Removing hardware from a water-cooled mini-ITX system is never easy either and, despite their size, more room in the 250D and Prodigy wouldn't go amiss if you intend on packing a high-end water-cooling system into one of them.

Having had some hands on time with Thermaltake's Core X1, I was suddenly aware of how much easier it made building a water-cooled mini-

ITX system. There's a huge amount of clearance between the motherboard and all the radiator mounts – so much so that, combined with a huge side window, you could create an attractive system, perhaps with acrylic tubing as well, which isn't often possible with mini-ITX cases. It might be larger than your average mini-ITX case – in fact, it's massive compared to Cooler Master's Elite 130 or Antec's ISK600 – but it's still small compared to your average ATX tower case, and it's blissfully easy to create a water-cooled system inside the Core X1 too.

So, back to the original question, I would say the Thermaltake Core X1 represents the upper limit, size-wise, and it still has its place. It can house so many radiators that you couldn't hope to generate enough heat to tax them, even if all the fans were running at 5V. However, if you've ever built a water-cooling system in a mini-ITX case then you'll probably appreciate the extra leg room you get when you're routing your tubing.

Specialtech is no more

It was with a sad heart that I recently read that Specialtech – one of the UK's longest-running online stores for water-cooling and modding hardware, closed its doors in February this year. I've worked with the company for numerous Custom PC features, and



Sadly, online water-cooling and modding store Specialtech is no longer with us

spent more money there than I care to admit to. In fact, it's been one of my favourite stores in the ten-plus years I've been into water-cooling and modding. I especially liked Specialtech's ability to stock the latest gear. It was one of the first in the UK to offer hardline acrylic tubing, plus it kept stock of many products from smaller brands that would likely never surface at larger retailers.

One of the reasons for its demise, though, is also one that will allow us to continue to get our mitts on cooling and modding gear. Put simply, many of the larger retailers have expanded their ranges of water-cooling hardware. This situation is great for water cooling, as it continues to grow in popularity, but it's plain to see that many people have been buying their systems with water-cooling gear from the likes of Scan and OcUK, rather than getting the latter separately.

It's a shame to see Specialtech go, but thankfully there are a few alternatives. Watercooling UK (www.watercoolinguk.co.uk), CandCCentral (www.candccentral.co.uk), Kustom PCs (www.kustompcs.co.uk) plus the larger Aquatuning (www.aquatuning.co.uk) are all well worth a look, while some UK-based companies such as XSPC have their own shops (<http://shop.xs-pc.com>).

Phobya and Cooler Master modding competitions

Bit-tech held its annual modding competition a few months ago, but there are two more competitions coming in the next few months and I'll be keeping an eye on them for any world-class entries. For starters, Cooler Master's Case Mod World Series, is the biggest competition of its kind, with dozens of entries and a huge prize pool too. Registrations have closed, so the action can now take place – you can see the entries at <http://mod.coolermaster.com>



The second competition is being held by Phobya, and it's giving three entrants its brand new WaCoolT OWL case, along with all the water-cooling gear they need, and there are £2,000 worth of cash prizes too.

In return, the entrants will be modding this huge water-cooling case, so make sure you check out the www.bit-tech.net modding section to see the latest entry designs. The

Phobya is giving three competition entrants its brand-new WaCoolT OWL case, along with all the water-cooling gear they need

community will then vote for its favourites to go forward and start modding.

Cosmos Cruiser by Brian Carter

Brian Carter, or Boddaker as he's known in modding forum circles, has shown us some of the best modding projects ever seen, and his incredible Neptune's Trident case mod even graced the front cover of **Custom PC** back in Issue 81. After a short lull in his output, following a series of commissioned projects, Brian has finally got back to building for himself and recently completed Cosmos Cruiser – a Cooler Master Cosmos II mod he's been working on since 2012.

This monstrous water-cooled PC is based on an automotive hotrod, and Brian employed nearly every trick in the book during its construction. The large orange side panel was made using a fibreglass mould, the front grilles were cut and sanded by hand, and the water-cooling tubes are covered in steel braiding, before passing into a custom manifold that directs the coolant to orange acrylic tubes on the other side.

Brian's project log is fascinating, and has all sorts of guides and tips, whether it's painting, water cooling or fibreglass you're investigating. You can see all the action at <http://tinyurl.com/cruisercosmos> **CPC**



Antony Leather is Custom PC's modding editor [@antonyleather](https://twitter.com/antonyleather)

How to Create your own Raspberry Pi 2 chassis

Raspberry Pi 2 cases might be cheap, but what if you want a unique custom design? Antony Leather shows how to make your own 3D-printed Pi 2 case

TOTAL PROJECT TIME / 3-6 HOURS

Last month we looked at using 3D printers for PC modding, taking you through the basics of using TinkerCad to design your objects. There's far more to TinkerCad than making 2D fan grilles and modding components, though, and this month we're going to use it to create a case.

Most reasonably priced 3D printers can only cater for sub mini-ITX motherboards, but Intel NUC and Raspberry Pi cases are definitely options for printers with 6in³ printing capacity or more. As Raspberry Pi 2 is the hot hobbyist product of the moment, we're going to create and print a custom-designed case for it using the 3D Systems Cube 3 printer, while also showing you how to go about creating your own. As the Raspberry Pi 2 is fanless and doesn't have any active cooling, this job is really easy and you can have some fun with the case design too.

TOOLS YOU'LL NEED



TinkerCad /
Free to use at
www.tinkercad.com



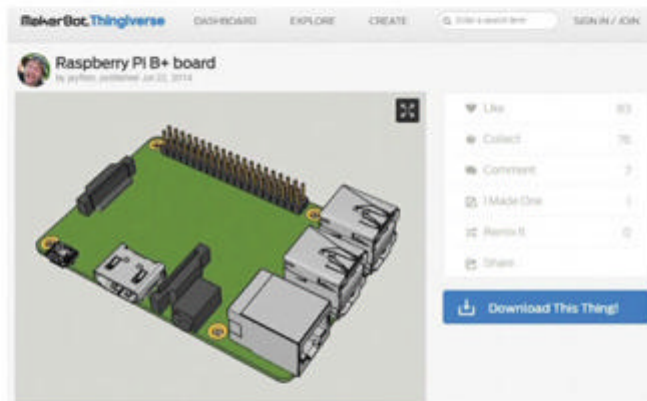
Digital vernier caliper /
Most hardware stores



3D printer or 3D printing
service - we used a 3D /
Systems Cube 3 from
www.printerland.co.uk

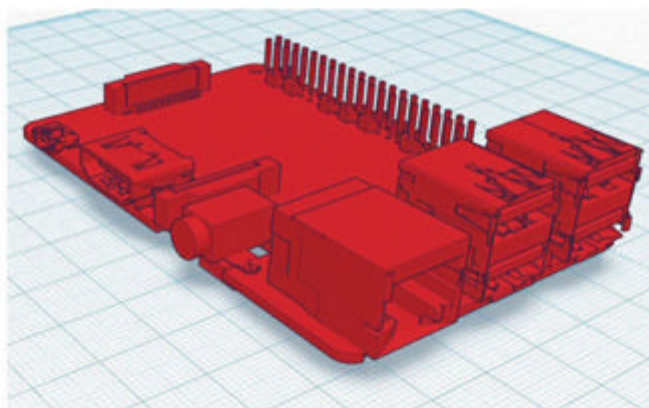


Finger files /
Most hardware stores



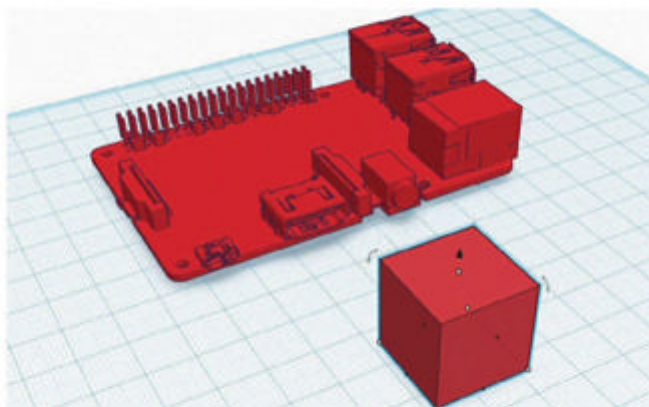
1 / DOWNLOAD RASPBERRY PI STL

To create your Pi 2 case, you first need a 3D model of the PCB. Thankfully the Pi B+ PCB is physically identical to the Pi 2 in terms of case layout, and is available to download for free from www.thingiverse.com. Search for the Raspberry Pi B+ board by jaytee and grab the 9MB STL file.



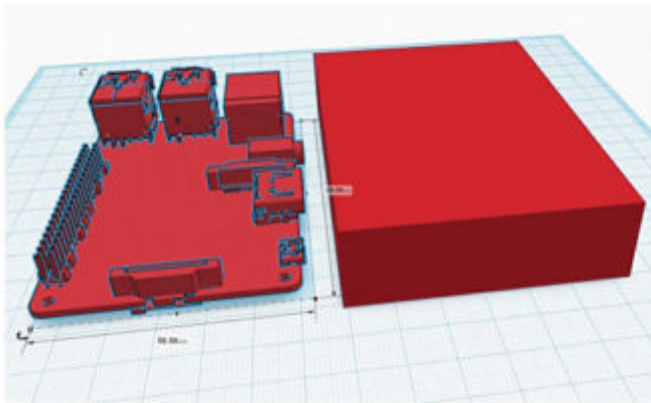
2 / IMPORT MODEL INTO TINKERCAD

Importing the STL file into TinkerCad (www.tinkercad.com) is easy, and you can then start to build your case around it. In the right-hand menu, under Import, simply point TinkerCad at your downloaded STL file and upload it.



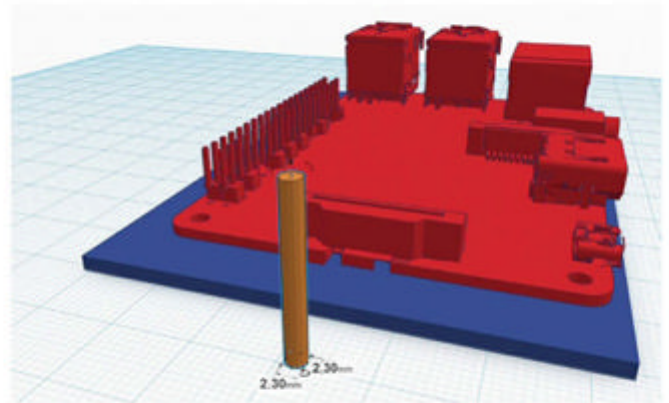
3 / START WITH A CUBE

Now you can start building the case, starting by dropping a cube shape into the workplane from the same menu. You can, of course, choose any shape but we'll be making a rectangular case so we're starting with a cube.



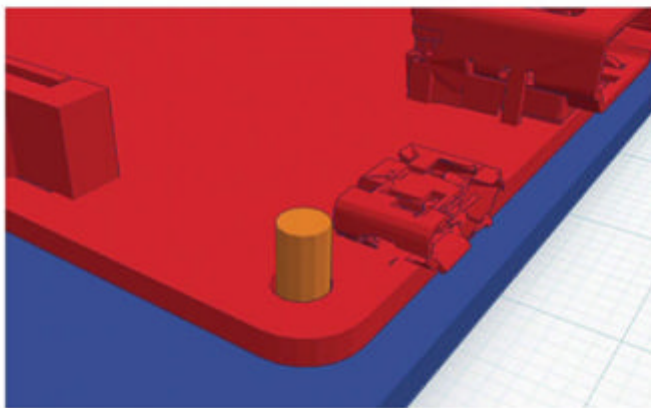
4 / ENLARGE CUBE TO FORM BASE

Modify the cube so it's the right size for the base of your case. You can either use the measurements provided by TinkerCad to guide you, or simply make the base a little larger than the PCB. The total PCB model size is 58.5 x 86.89mm, so your base needs to accommodate that area measurement.



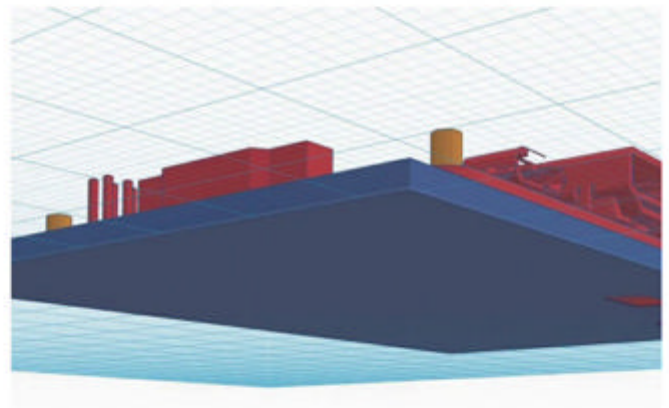
5 / CREATE SCREW HOLE INSERTS

With the PCB lined up on your base, create some cylinders for inserting holes into the case to mount the PCB. You can use standard PC screws – just make a cylinder that's slightly smaller than the screw thread (a digital vernier caliper will come in handy), so the screw can bite into the plastic.



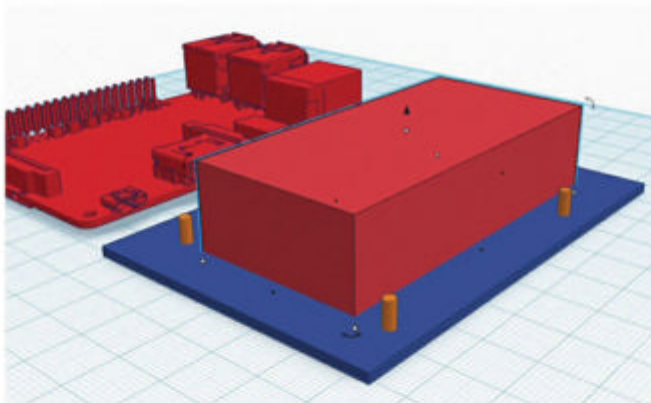
6 / PLACE INSERTS INTO BASE

Move the inserts onto the case and position them in the PCB mounting holes, in order to ensure they line up once the case is printed – another good reason to have a 3D model of the PCB to hand.



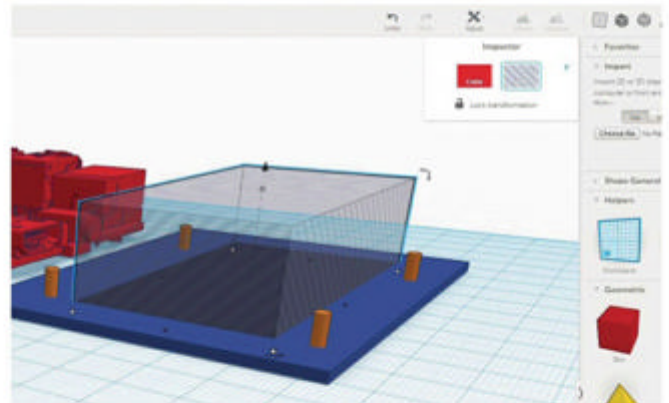
7 / CHECK BASE FOR CLEARANCE

You now need to raise up the inserts, so they don't go all the way through the base when you convert them into holes. Lift them by 3–4mm so the screws can pass a little way into the base – you can check they're clear by looking underneath the case.



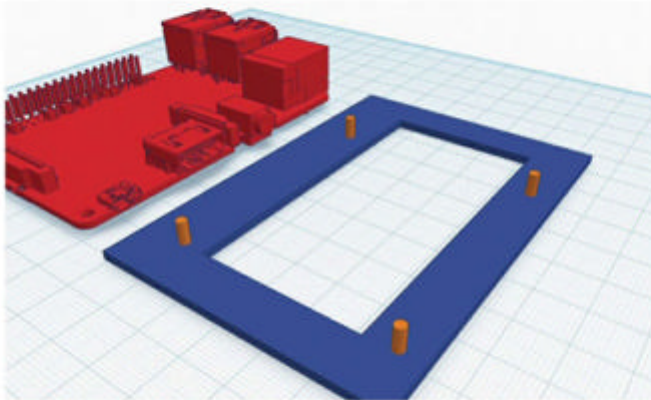
8 / CREATE CUT-OUT INSERT

As we saw in last month's 3D printing feature, it's best to create holes in as many parts of your project as possible to cut printing time and costs. We started by laying down a large object in the base to create an opening – we're also moving the PCB model out of the way for now.



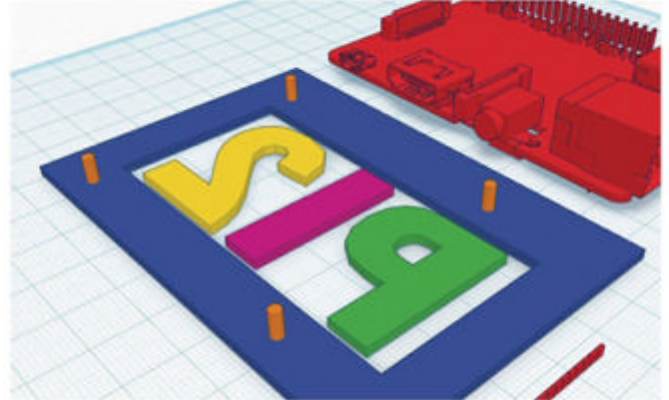
9 / SWITCH TO HOLE MODE

Now convert the object into a hole by selecting it, then clicking on Hole in the Inspector box, which converts it from a coloured object into a hole. It should now appear translucent, which indicates that it's acting as a hole and not a solid object.



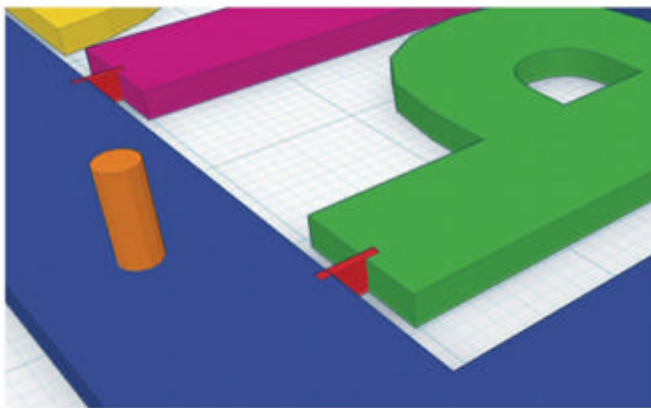
10 / GROUP OBJECTS

To finish creating the hole, select the base and hole only (leave the mounting holes separate for now), and select Group from the top toolbar. This process will delete the area of the base with which the hole is merged.



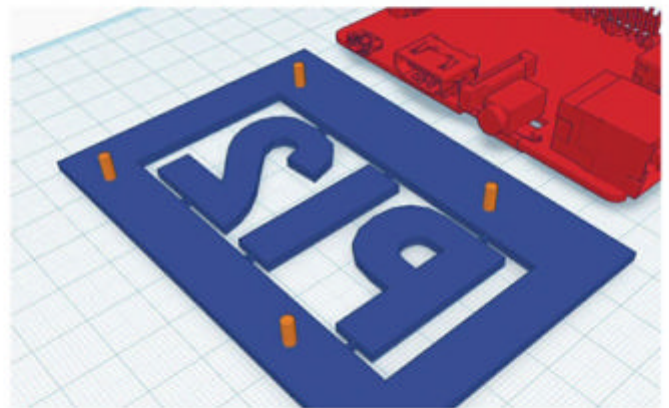
11 / CREATE CUT-OUT DESIGN

You can then create a vent using individual pieces or, as we did, drop some letters and numbers into place. You can simply enlarge or reduce them to size as needed, depending on your chosen vent design, or you could lay them on top.



12 / INSERT SUPPORTS

To hold the characters in place, we created small supports that connect them to the case at the edges. They'll still look like they're suspended, but this reinforcement will help them to survive any knocks. We also reversed the lettering, so it will read the right way when you pick up the box.



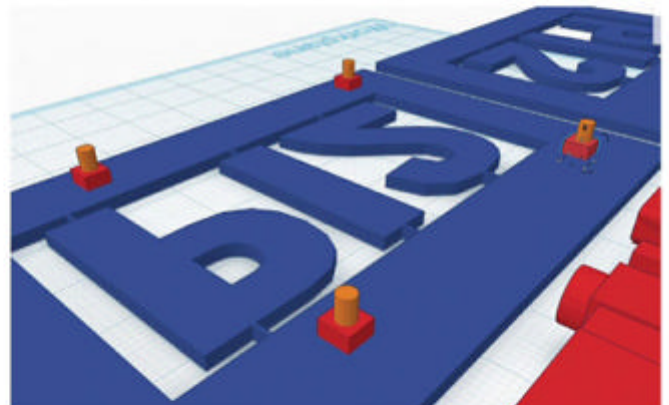
13 / GROUP OBJECTS

Merge your vent design objects into one group by selecting them and clicking the Group icon again, being careful to avoid any objects that you don't want to group yet.



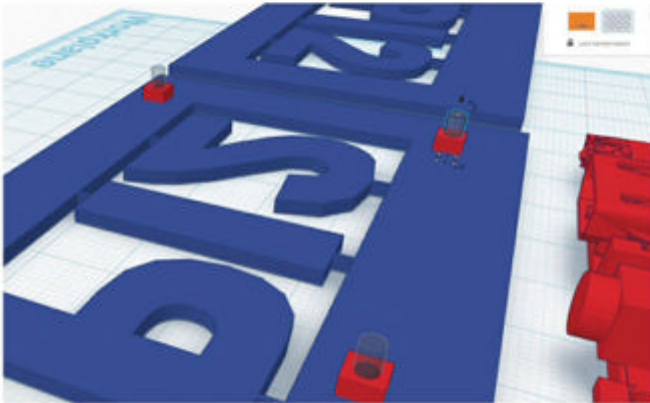
14 / CLONE BASE

We want to apply the same design to the lid of the case, and the easiest way to do this job is to clone the entire base, then remove the PCB support holes as shown. You can move the lid to one side for now.



15 / ADD PCB STANDOFFS

You don't want to screw the PCB directly into the base, so create some small standoffs into which you can insert screws. These bits are just like the standoffs in a PC case, except you only need them to be 5mm or so high. Place these standoffs over the mounting holes.



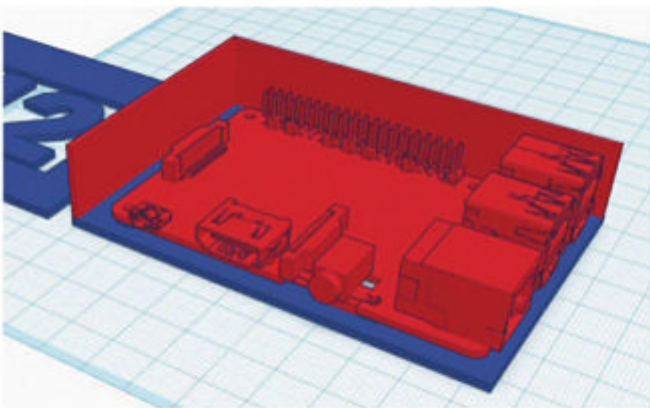
16 / CREATE HOLES

You can now convert the mounting holes from solid objects into holes. Check they're aligned with the standoffs, then click on each one and convert it into a hole using the same method employed in step 9.



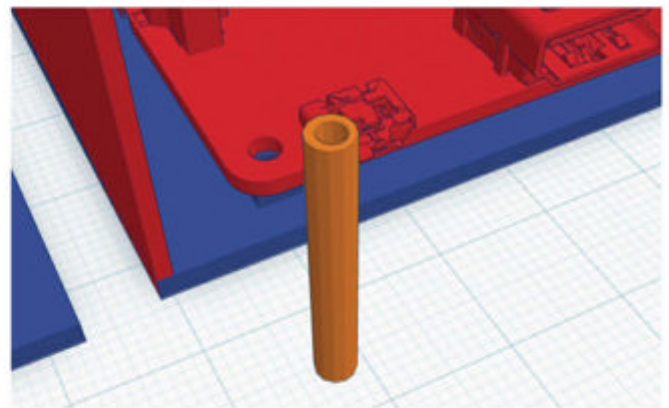
17 / GROUP OBJECTS

In the same way you grouped the vent objects together, you can now group all the base objects together so you can move on. Hold down the left mouse button down, as you would to select an area in Photoshop, or characters in Word, then click the Group button in the top menu.



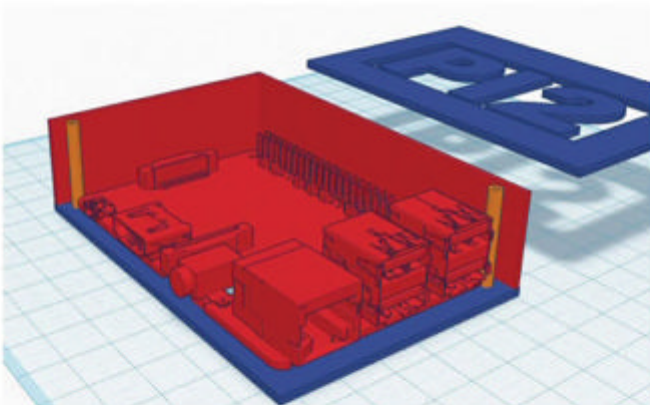
18 / CREATE SIDES

Now put the PCB model back in place and create some side sections. Only two sides of the Raspberry Pi 2 have ports, so the other two can be solid objects. We dropped in a couple of cube shapes and manipulated them to form 3mm-thick walls that run from end to end as shown.



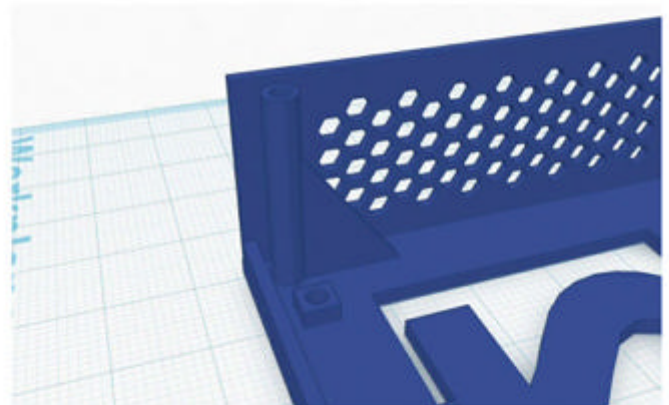
19 / CREATE LID MOUNTS

You'll need a way to mount the lid too. You could have a sliding lid, but we preferred the idea of securely screwing it into place. We created two mounts that could sit inside the case, level with the side sections.



20 / INSTALL LID MOUNTS

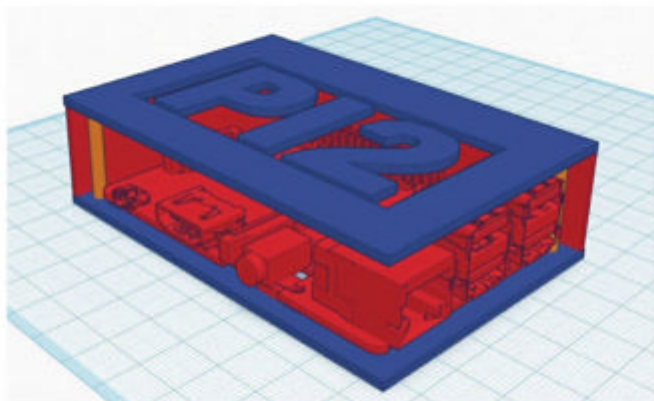
These mounts sit diagonally from each other, and only two are needed so save space – most of the lid will rest on the base's side sections anyway. We've placed the mounts so that there's still enough clearance between the PCB and the side sections – at least 2–3mm.



21 / ADD LID MOUNT SUPPORTS

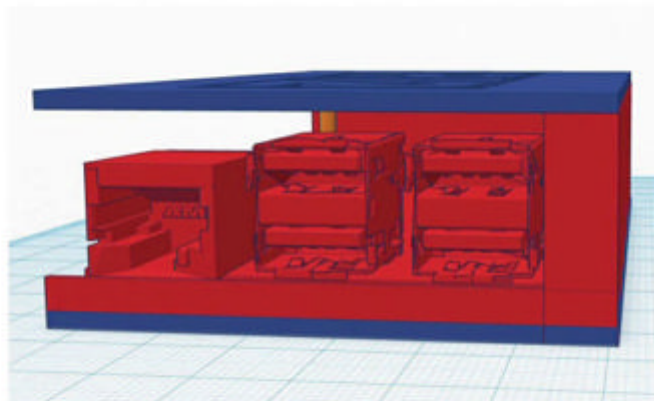
We went through to the end and printed a test base at this point, but found the supports were too weak, breaking when screwing the lid into them. We went back and added these corner braces to strengthen them. You can also add vents in the sides – we opted for a hexagonal pattern.





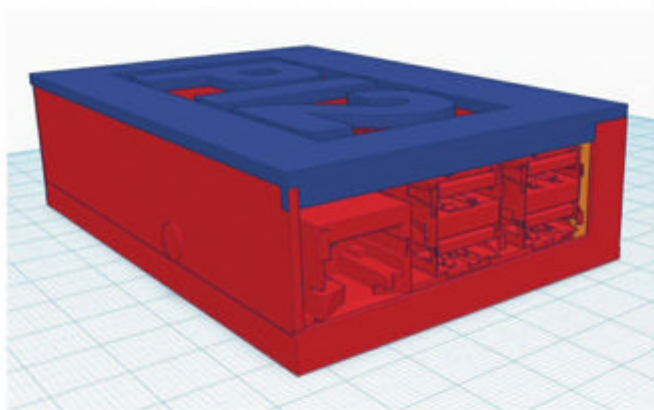
22 / PLACE LID

Now you can move the lid into position, lining it up with the base and side sections. You can then move on to finishing the side sections and creating holes for the mounting screws.



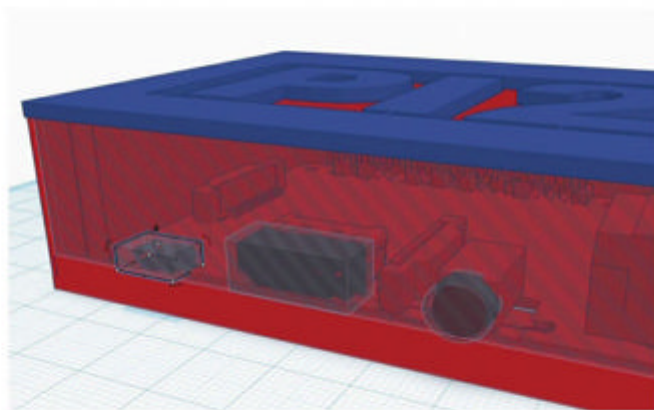
23 / SURROUND PORTS

You don't really need to create a sealed case with the Raspberry Pi 2, but a sealed case definitely looks neater, so we went some of the way, and surrounded the end ports at the side and the bottom by extending the lid.



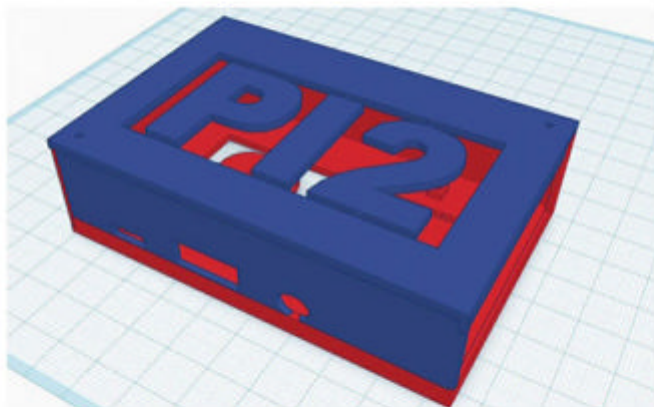
24 / CREATE PORT SIDE SECTION

We then added a further surround in the lid section, as well as a long side section as the final piece – we'll cut holes into this part through which the ports can protrude. The idea will be to delete the PCB model, leaving a 3D-printable, two-part case.



25 / CONVERT TO HOLE

By converting the side section to a hole, it becomes translucent so you can see the ports you need to cut out to provide access. There are just three – the HDMI port, micro-USB connector and audio output.



26 / ADD PORT AND LID HOLES

You then just need to recreate the ports from appropriately shaped objects, then resize them to provide plenty of clearance around them. For the HDMI port, we opted for a rectangular hole, rather than a larger-sized hole shaped like an HDMI port, to ensure there was enough clearance.



27 / PRINT YOUR DESIGN

Click on Design, then Download for 3D Printing to get the STL file for your design, and either print it on your own 3D printer or use a third-party service, then enlarge any troublesome holes and file the edges. Here's our design, printed on a 3D Systems Cube 3, with a Pi 2 installed. **CPC**



bitGamer

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Readers' Drives

Loramentum



Inspired by a university entrance hall computer project, Alexander Banks decided to build a fully water-cooled PC that could be wall-mounted

CPC: What originally inspired you to build Loramentum?

Alexander: A couple of years ago, one of my university professors had an idea for a main foyer display. The plan was for the students to create individual transistors that could be linked up to form a low-powered computer, capable of running simple programs. The whole

assembly would have been mounted flat on the wall of the entrance hall to the engineering department. This idea got me thinking, and I thought it would be a fun project to mount consumer-level hardware in a similar fashion, but including the cooling in the design. Coincidentally, a number of other high-end, wall-mounted builds were completed during the planning stage for this project – convergent design at its best, it seems.

Unlike other wall-mounted systems, I wanted this one to remain relatively portable so I could bring it to LAN events and shows. Naturally,

this idea conflicted quite heavily with the original concept, spawning many of the design decisions found in the final build.

CPC: Where does the name come from?

Alexander: It actually stems from the Latin for frame, strap or thong. I felt it was fitting, given how the hardware would be framed against the wall, completely on display.

CPC: What specs did you choose, and why?

Alexander: It's mostly a light gaming and everyday-use PC – I wanted to have my workhorse PC whirring away on its own while using this machine for winding down. I'm also planning on getting back into the LAN scene, so I figured a fun, showy rig would fit the bill.

The hardware itself is quite beefy, although relatively modest when compared with some of the big-time mods around. I was fortunate enough to be provided with a Core i7-4770K by Intel, which was really the deciding factor on building this rig. I went with the Asus Z87 Pro-I motherboard for a couple of reasons, the first being the space-saving nature of mini-ITX, the second being that it had the most suitable layout for this project. I'd originally planned a different colour scheme, but decided on black and gold/yellow in order to fit the board's colours.

Meanwhile, the AMD R9 290 GPU is a solid performer with a great speed to price ratio. Similarly, the RM650 power supply was chosen, as it could run mostly in fanless mode, and it also had a very good cable pin layout, which is important for a build such as Loramentum. EK Waterblocks was also kind enough to provide almost all the water-cooling components.

CPC: What other mods have you built?

Alexander: Only a handful. My first modding project, Azure, is my workhorse that I use for 3D modelling, rendering and animation. It's a beefy X79 system running a pair of GTX Titan cards with dual water-cooling loops in an NZXT Phantom 820 case. It was particularly exciting, as it featured acrylic tubing, which at the time was still pretty new territory.

Conversely, my other project, Vesper, is a tiny case for an Intel NUC. Vesper was designed for bit-tech's NUC enclosure competition; it currently acts as a media streamer for the living room. The main chassis was 3D printed (see Issue 140, p93), with the centre finished with French-polished vavona burl veneer.

CPC: What difficulties did you come across?

Alexander: The main difficulty was working out how to make the main chassis. I don't personally have access to CNC machinery, which was required in order to build the chassis in the way I



/MEET THY MAKER

Name Alexander Banks

Age 22

Location London

Occupation Student

Main uses for PC Light gaming, web browsing and general fun

Likes Good food and cooking, fungi hunting, XC mountain biking, photography and of course excessive modding!

Dislikes Drum and bass, goat's cheese and people who are too serious for their own good

SYSTEM SPECS

CPU Intel Core i7-4770K

Graphics card Asus AMD Radeon R9 290

Memory 16GB (4 x 4GB) Corsair Dominator Platinum 1,866MHz

Motherboard Asus Z87I-Pro

Storage 256GB Samsung SSD 840 Pro

PSU Corsair RM650

Cooling EKWB and XSPC custom loop based on a 360mm x-flow radiator

SEE THE FULL
PROJECT LOG:

[http://tinyurl.com/
CPCloramentum](http://tinyurl.com/CPCloramentum)



wanted, so I looked to the community. Thankfully, bit-tech user Phame and Parvum Systems were happy to lend a hand.

The biggest headache came towards the end of the build, however. I was in the process of building the stand and had placed the near-completed build on top of the stand to test it. I left the room to fetch the tools needed to make the mounting brackets, then I heard an almighty crash. The rig had fallen off the table onto the floor, shattering large portions of the chassis. I'm still amazed that all the

hardware survived intact, as it was quite an impact. I used this experience as an opportunity to improve the design, the new one being 45 per cent lighter, just as strong and generally more efficient.

CPC: What materials did you use?

Alexander: The majority of the rig is constructed from machined acrylic; the chassis is formed from two 10mm-thick plates topped with a 5mm thick matt black blanking layer. I chose acrylic, as it's fairly easy to machine and has good optical clarity. I considered

switching to polycarbonate, but my approaching deadlines persuaded me to stick with my original choice. The two acrylic chassis pieces form a sandwich, with the channels kept watertight via a set of custom-length O-rings. The O-rings themselves were very simple to make – it was just a case of carefully supergluing the correct lengths of O-ring cord.

I decided to gold-plate the RAM heatspreaders, GPU block and EK logos in order to fit with the theme. Plating with real 24-carat gold produces a very distinct look when





compared with gold paint, and it's especially apparent when you see the machine in real life. I tried to balance out the total gold content of the build so that it didn't end up looking tacky or over the top – mixing the finishes and hues really helped in this respect.

Meanwhile, all the wiring was done from scratch using 16 AWG cable, which fills out sleeving much better than standard 18 AWG cable.

CPC: What tools did you use?

Alexander: If only I could list a CNC milling machine here, but unfortunately that's beyond my scope. I mostly used very standard tools. For this project, I used a Dremel 4000, along with a selection of DeWalt cordless tools

(drill, jigsaw and circular saw for the flight case).

The stand was made at home using just a jigsaw, some files, some glue and a lot of sandpaper.

CPC: What media interest has the project attracted so far?

Alexander: I'm rather surprised by just how much attention this build has garnered so far. It's been featured on the Facebook pages of MNPCTech, EKWB, Asus NA and PC Casegear, and it's also won Mod of the Month on Overclock.net and bit-tech. It did remarkably well on Reddit, too which has a rapidly growing community of PC building enthusiasts.

CPC: How long did the build take?

Alexander: In truth, it didn't take that long. While I had started the project near the beginning of 2014, a lot of that time was spent either waiting for parts or simply not having enough time to progress. When the chassis was smashed in September, I basically had to begin much of it from scratch. As such, I would say it realistically it only took two or three months.

CPC: What did you learn from the build process?

Alexander: This build has been a truly fantastic learning experience. I had had little to no experience in

designing pieces for machining, nor any experience in building wires from scratch. While I'd had a few years of experience with CAD programs beforehand, I hadn't really pushed the rendering side as hard as with Loramentum, and in the process, I learned an awful lot about constructing realistic 3D materials and using lighting. I also used this project as an opportunity to improve my photography skills. While they still have a long way to go, they're vastly improved when compared with how they were this time last year. Crucially, I also learned not to leave a rig balancing on an unfinished stand on the edge of the dining room table.

CPC: Are you happy with the end result?

Alexander: I'm definitely happy with the finished result, although there are parts I would like to tweak. One would be switching the PSU to a smaller SFX model. My choices were limited back when I was planning it, and many SFX PSUs were said to be quite loud, which wouldn't be appropriate for an open rig. Nowadays we have more choice, and using an SFX PSU would free up a lot of space. M.2 SSDs are also a great option that's now available, removing an extra set of wires and again simplifying matters further. **CPC**

BE A WINNER

To enter your machine for possible inclusion in Readers' Drives, your mod needs to be fully working and, ideally, finished based in the UK. Simply log on to www.bit-tech.net and head over to the forums. Once you're there, post a write-up of your mod, along with some pics, in the Project Logs forum. Make sure you read the relevant rules and advice sticky threads before you post. The best entrant each month will be featured here, where we'll print your photos of your project and also interview you about the build process. Fame isn't the only prize; you'll also get your hands on a fabulous selection of prizes – see the opposite page for details.

Win all these prizes!

We've teamed up with some of the world's leading PC manufacturers and retailers to offer this great range of prizes to each lucky Readers' Drives winner. If your creation is featured in the magazine then you'll walk away with all of the prizes listed on this page, so get in your entries!

Corsair graphite Series 230T case and RM 550w Modular power supply

TOTAL VALUE £150 inc VAT / **MANUFACTURER** www.corsair.com

Corsair believes that a great PC starts with a great case. The Corsair Graphite Series 230T is a compact expression of this core philosophy. With stylish looks and a choice of three different colours, it packs in a remarkable number of features to provide builders with tonnes of room for expansion and amazing cooling potential. Like all Corsair cases, it's built using the finest materials and finished to the highest standards, so it will withstand several years of upgrades. Plus, to make sure it stand out from the crowd, the 230T features Corsair's new Air Series LED high-airflow fans, providing distinctive lighting with low-noise, high-airflow cooling.

Just as a quality case is essential to building a quality PC, a high-performance, a high-quality power supply is also a vital ingredient. The all new RM series has been built from the ground-up to deliver unmatched reliability alongside 80Plus Gold efficiency, and all with the absolute minimum of noise. It uses specially optimised quality parts to reduce sound at the component level, and it's completely silent below 40 per cent load, thanks to its Zero RPM fan mode. It's also fully modular, allowing for the maximum amount of flexibility during installation. With a Corsair Graphite 230T case and an RM 550W Modular power supply at the heart of your build, you'll have the foundations for a truly awesome gaming machine.



Mayhems coolant and dyes

VALUE £50 inc VAT / **MANUFACTURER** www.mayhems.co.uk



Cooling performance is only one part of the equation when it comes to kitting out your rig with custom water-cooling gear. The other major bonus is that all those tubes and gleaming fittings just make your PC look damn sexy, and they look even better when they're pumped full of fancy coloured coolant. As such, we're particularly pleased to have the folks at Mayhems now on board with Readers' Drives; they're currently offering two 1-litre bottles of Mayhems' Pastel Ice White coolant, along with a selection of five dyes, so you can choose the colour that best complements your PC. Check out the blue coolant in our own mini PC mod on the cover of Issue 109 for an example of what's possible with some Mayhems coloured coolant.

Phobya Modding Kit

VALUE £50 inc VAT **MANUFACTURER** www.phobya.com, www.aqua-tuning.co.uk

The Phobya modding kit is designed with the modder in mind, offering great value for money and quality products. The kit includes Nano-G 12 Silent Waterproof 1,500rpm multi-option fans, which use an innovative fan-blade design. As standard, the fans include braided black cables to keep your case looking as neat as possible. The fans are also supplied with a special cable that lets you run the fan at 5V rather than 12V, reducing the noise emitted in order to help you to build a silent system.

The kit also includes the 60cm Phobya 3-pin Molex to 4x 3-pin Molex Y-cable. This pre-

braided extension cable gives you extra routing options in your case, and it also enables you to run up to four fans from one compatible

motherboard header. Meanwhile, the Phobya SATA 3 cables included in the kit offer the same great quality braiding as the rest of the Phobya range, while also securing your connection with latched connectors.

As well as this, the kit includes the Phobya SlimGuide Controller, which gives you the option to vary the speed of other fans in your case, while the Phobya TwinLEDs let you shine a light on your mods.





Folding@Home

Join our folding team and help medical research

Folder of the month / We catch up with: Bedders

CPC: So who is Bedders?

Bedders: I'm David, and I'm an IT technician and webmaster from the north west of England. I'm a keen gamer, playing everything from first-person shooters and strategy games to puzzle games and RPGs.

CPC: Why did you start folding?

Bedders: I bought a copy of Custom PC a few years ago, and thought that using spare hardware to help medical research sounded like a neat idea. It's only in the last few months that I've decided to do it on a regular basis every evening.

CPC: What excites you most about folding?

Bedders: The competitiveness! Seeing myself climb the rankings of the CPC Folding group is immensely satisfying. The fact that I'm helping people and not letting my rig sit idle all the time is also a great motivator.

CPC: How many machines do you have folding?

Bedders: Just my gaming rig at



home. It has a Core i7-4770K, a Corsair H100i cooler, two EVGA GTX 780 SCs in SLI, 32GB of 1,333MHz Corsair Dominator RAM and a Samsung 840 EVO 256GB. None of this kit is overclocked, as it gets warm enough already. I use Windows 7 Professional 64-bit, but I'll be upgrading to Windows 10 when it comes out, since it's free. I only recently obtained the second graphics card, but wish I'd done so sooner! They make quite a team, producing over 100K ppd each.

CPC: Do you intend to keep up your current production level?

Bedders: I intend to keep folding every evening. It helps to keep my room nice and warm when I get up in the morning.

CPC: Any tips for fellow team members?

Bedders: It doesn't matter if you can't fold 24/7, or do it every evening – as long as you complete any work unit you start within the time, you can do it whenever is best for you.

CPC: What do your friends and family think about your folding?

Bedders: My dad pays the electricity bill, and he hasn't complained yet! To be honest, they don't know much about it.

CPC: What's your worst folding experience?

Bedders: I haven't actually had any bad experiences. There have been no hardware failures, no stressed components. Yet.

CPC: And the best?

Bedders: I've recently hit the 5 million mark. I never thought that I'd get that high when I first started!

CPC: If you could change one aspect of your folding setup at home, what would it be?

Bedders: I would get a second PC to run 24/7. Only folding during the evenings is hurting my production rate.

WHAT IS FOLDING?

Folding@home uses the spare processing cycles from your PC's CPU and graphics cards for medical research. You can download the client from <http://folding.stanford.edu> and our team's ID is 35947. Once you pass a significant milestone, you'll get your name in the mag. You can also discuss folding with us and other readers on the www.bit-tech.net forums.

STATS

Team rank 229

World rank 10,916

Score 6,212,405

Work units 479

Daily points average 14,796

TOP FOLDERS: This month's shout-outs go to HHComputers, BeezaBob and Wilding2004. If you fold under any of these names, email folding@custompcmag.org.uk

MILESTONES THIS MONTH

USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE	USERNAME	POINTS MILESTONE
alpha00	20000	Quozzbat	400000	ghodula	2000000	Wilding2004	6000000
oOHaydezOo	20000	GarethFlatlands	500000	kcanti	2000000	Dave_Laffin	7000000
Huddo	30000	Sonic67	500000	Osiris_Blue	2000000	toothytech	7000000
Matt_Livermore	30000	Chrissebooboo	600000	TrekkieStu	2000000	queluomo1	8000000
Alee4177	40000	Damien_Tanner	600000	Uncle_Fungus	2000000	Semmy	8000000
Seamus3900	40000	GJBriggs	600000	gKitchen	3000000	Portchylad	9000000
Shaun	40000	HolyCow	600000	Ken_Swain	3000000	Dickie	10000000
Trunkey	40000	Catflaps	700000	RDL_Mobile	3000000	Grimpeeper	10000000
ZardozSpeaks Anonymous	40000	Epwin	700000	Tommeye123	3000000	BeezaBob	20000000
MikePreston	60000	Hateboy	700000	andysroms.com	4000000	Oatyflapjack	20000000
Unstoppable	60000	Adam_S_James	800000	Brentwood- Computers.com	4000000	TheAbyssDragon	20000000
Parmesan	80000	carbontwelve	800000	PaddyandStuff	4000000	8Core	60000000
stubbler	80000	DJcarrot	800000	Vinneh	4000000	HHComputers	60000000
Ch1nb34rd	100000	ligmon	800000	CaptChadd	5000000	mmorr	60000000
LynnRFlye	100000	lilmatt157	800000	Flowwwie	6000000	apeman556	70000000
Urumiko	100000	Sparrowhawk	800000	GreenDemon360	6000000	Desertbaker	100000000
ZeDestructor	100000	BondyBoy	900000	Mem	6000000	Lordsoth	200000000
Dustspeck101	200000	techknowledgey	900000			Scorpuk	500000000
KONRAD	200000	varnis	900000				
MarkVarley	200000	Aedin	1000000				
purerrizzo	200000	andboo1	1000000				
J3llyf1sh-UK	300000	robertmather	1000000				
PernusBernus	300000	robgsxrk4	1000000				
Ganey	400000	ssjandu	1000000				
		Andy_J	2000000				

THE NEXT OVERTAKE

WORLD RANK	TEAM NAME	POINTS	DAILY POINTS AVERAGE	TIME UNTIL OVERTAKE
8	Custom PC & bit-tech	14,901,469,329	17,190,948	0

TOP 20 OVERALL

RANK	USERNAME	POINTS	WORK UNITS
1	Nelio	2,321,156,154	102,306
2	DocJonz	978,614,271	170,289
3	coolamasta	677,834,587	157,839
4	Scorpuk	509,330,329	13,800
5	StreetSam	485,821,945	88,038
6	Dave_Goodchild	455,995,441	117,265
7	piers_newbold	366,266,574	36,551
8	johnim	290,064,177	78,602
9	phoenicis	250,044,587	95,660
10	PC_Rich	249,994,439	70,230
11	Slavcho	228,915,080	31,637
12	Wallace	212,477,027	6,204
13	zz9pzza	211,014,628	15,794
14	Lordsoth	203,410,067	89,491
15	The_M2B	197,420,454	53,249
16	Ben_Lamb	166,053,146	2,891
17	Christopher_N_Lewis	152,383,638	35,871
18	TheFlipside	149,573,674	19,261
19	Lizard	131,878,662	60,132
20	KevinWright	127,942,515	25,731

TOP 20 PRODUCERS

RANK	USERNAME	DAILY POINTS AVERAGE	OVERALL SCORE
1	Nelio	2,136,658	2,321,156,154
2	HHComputers	1,350,000	63,066,008
3	StreetSam	1,344,056	485,821,945
4	DocJonz	1,306,099	978,614,271
5	Scorpuk	994,519	509,330,329
6	PC_Rich	840,733	249,994,439
7	johnim	724,455	290,064,177
8	coolamasta	621,929	677,834,587
9	TheFlipside	553,444	149,573,674
10	Slavcho	553,074	228,915,080
11	The_M2B	464,191	197,420,454
12	Lordsoth	456,414	203,410,067
13	piers_newbold	427,721	366,266,574
14	Laguna2012	427,528	116,821,300
15	Desertbaker	419,577	108,883,348
16	apeman556	373,656	78,181,036
17	TrilithiumInjector	262,703	48,263,217
18	BeezaBob	193,484	20,199,325
19	Wilding2004	182,016	6,299,768
20	Roveel	171,821	47,012,485



JAMES GORBOLD / HARDWARE ACCELERATED

MONITOR MIND-BOGGLER

Choosing a new monitor is now harder than ever, argues James Gorbold

I've always thought that display quality is the most important characteristic of any PC setup, as the monitor is the only component with which you continuously interact. In fact, I'd go so far as to say that I'd rather have a slow PC with a high-quality display than a fast PC with a miserable monitor.

In the past, choosing the right monitor was relatively easy, as you only had four factors to consider: resolution, screen size, image quality and price. I say easy, as the larger resolution and screen size you could afford, the better, while even image quality can often be simplified to this simple statement: IPS = good, TN = not so good. That's a gross simplification, of course, especially as the vast majority of us aren't on an unlimited budget, so we have to strike a balance between all four factors.

However, it's recently become even more complicated to choose a new monitor. The first problem to rear its head is the explosion in the number of resolutions and aspect ratios to consider. Using traditional thinking, you would simply buy the highest-resolution monitor available, 4K or 5K. However, 4K and 5K monitors have serious shortcomings. Their major problem is that they suffer from horrendous tearing and lag, mainly due to the way the DisplayPort bus has to split and then recombine the data output from the graphics card into multiple streams.

Having tested and used every 4K and 5K monitor currently available in the UK, I can confidently say that the tearing you see on such monitors means I simply wouldn't want one on my desk long-term. The next step down from 4K and 5K is 3K, but while 3K monitors don't tend to suffer from the same

tearing and lag as their more expensive brethren, there are still question marks over 3K monitors, because they have a 'non-standard' aspect ratio of 21:9, compared to the more usual 16:9. And while a wider aspect ratio is fantastic for multitasking in Windows, many games don't scale well, or in some instances not at all, over the super-wide aspect ratio. Arguably, this leaves a 2,560 x 1,440, 16:9 monitor as the best choice for PC enthusiasts right now.

The good news about choosing a 2,560 x 1,440 (or 1,920 x 1,080 if you can't afford the former) monitor, is that there's a plethora of panel types available at these resolutions. However, you still need to be careful, as there are two competing standards of sync technology to consider. Sync technology, known as G-Sync in the Nvidia camp and FreeSync in the AMD camp, synchronises the refresh rate of your monitor with the frame rate of your graphics card, reducing tearing and stuttering, making gaming a more pleasant experience.

G-Sync has been available for over 18 months, so the technology has matured into some really great monitors. FreeSync is considerably younger, only making its way onto the market in the past month or so, so there's a much more limited choice of monitors available. The first batch of FreeSync monitors have also suffered from a lower minimum refresh rate than some G-Sync monitors, limiting the available frame rate at which tearing can be eliminated. Still, it's great to see monitor manufacturers embracing both technologies and I don't think it will be too long till we see monitors that support both G-Sync and FreeSync, giving you more flexibility when choosing a graphics card. **GPC**

In fact, I'd go so far as to say that I'd rather have a slow PC with a high-quality display, than a fast PC with a miserable monitor

James Gorbold has been building, tweaking and overclocking PCs ever since the 1980s. He now helps Scan Computers to develop new systems.



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